Conceptual Design for the Present Landfill Closure Cover Rocky Flats Environmental Technology Site

Prepared for Kaiser-Hill, LLC
Golden, Colorado

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Foreword

This *Conceptual Design for the Present Landfill Closure Cover, Rocky Flats Environmental Technology Site (*Conceptual Design Report or CDR) was developed to evaluate the feasibility of constructing an evapotranspiration (ET) cover over the Present Landfill instead of a traditional Subtitle C cover. Modeling has been conducted to evaluate the water balance aspects of the ET cover that indicate the ET cover is feasible and will provide equivalent performance to a traditional cover.

In some cases, the CDR provides options for actual construction without indicating a preference. For example, on-site and off-site borrow sources are cited and options for relocating waste and not relocating waste are suggested. These options will be evaluated during the next phase of the design process. The CDR also outlines data gaps that must be filled in the next phase of the design process.

The CDR will be used to support the development of an Interim Measures/Interim Remedial Action decision document for the implementation of a cover and groundwater remedy. Groundwater remediation/diversion is not addressed in the CDR and will require additional investigation and design efforts.

The CDR will also be used to develop the scope of work required to complete the design of the cover. The concepts and information provided in the CDR will be the basis of the final design and construction.

The CDR presents the overall conceptual design for the final cover of the Present Landfill The main report is supplemented by appendices that provide the modeling, reports, and calculations conducted during the conceptual design.

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List of Acronyms and Abbreviations

AC	Acre
ACAP	Alternative Cover Assessment Program
ASTM	American Society for Testing and Materials
ARARs	Applicable or relevant and appropriate requirements
ATT	Advanced Terra Testing, Inc.
CDR	Conceptual Design Report (*Conceptual Design for the Present Landfill Closure Cover, Rocky Flats Environmental Technology Site)*
CDPHE	Colorado Department of Public Health and Environment
cfm	Cubic feet per minute
cfs	Cubic feet per second
CH_4	Methane
cm	Centimeters
cm/hr	Centimeters per hour
cm/s	Centimeters per second
CO_2	Carbon dioxide
CQA	Construction Quality Assurance
CUHP	Colorado Urban Hydrograph Procedure
cy	Cubic yards
DBS&A	Daniel B. Stephens & Associates, Inc.
DOE	U.S. Department of Energy
DR	Dimension ratio
DUDFCD	Denver Urban Drainage and Flood Control District
EA	Each
EPA	U.S. Environmental Protection Agency
ET	Evapotranspiration
FML	Flexible membrane liner
FOS	Factor of safety
g	Gravitational force
g/cm^3	Grams per cubic centimeter
gpm	Gallons per minute

List of Acronyms and Abbreviations (Continued)

HAP	Hazardous air pollutant
HDPE	High-density polyethylene
HD	Water content below which plant transpiration starts to decrease (used in UNSAT-H)
HDS	Heat dissipation sensor
HN	Water content above which plants do not transpire because of anaerobic conditions (used in UNSAT-H)
HR	Hour
HW	Water content below which plants wilt and stop transpiring (used in UNSAT-H)
in/hr	Inches per hour
KH	Kaiser-Hill, LLC
K_{sat}	Saturated hydraulic conductivity
LAI	Leaf area index
LandGEM	Landfill Gas Emissions Model
LF	Linear foot
LFG	Landfill gas
lgp	Low ground pressure
LS	Lump sum
m^3	Cubic meters
Mg	Megagrams
mm	Millimeters
NCDC	National Climatic Data Center
NCRP	Non-criteria reportable pollutants
NMOC	Non-methane organic compounds
O&M	Operations and maintenance
OU5	Operable Unit No. 5, Original Landfill at the Rocky Flats Environmental Technology Site
pcf	Pounds per cubic feet
POCs	Points of compliance
PSD	Prevention of significant deterioration
psf	Pounds per square feet

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List of Acronyms and Abbreviations (Continued)

RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFETS	Rocky Flats Environmental Technology Site
RMA	Rocky Mountain Arsenal
RT	Roundtrip
RUSLE	Revised Universal Soil Loss Equation
TDR	Time-domain reflectometry
UNSAT-H	Computer model for calculating water and heat flow in unsaturated media
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VOC	Volatile organic compound
WBAN	Weather Bureau, Army, and Navy
WEPP	Watershed Erosion Prediction Project
YR	Year

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Executive Summary

This report, *Conceptual Design for the Present Landfill Closure Cover, Rocky Flats Environmental Technology Site* (Conceptual Design Report or CDR) presents the preliminary design basis and performance justification for a final cover planned for the Present Landfill, at the Rocky Flats Environmental Technology Site (RFETS). The planned final cover is an evapotranspiration (ET) cover, which relies on the natural processes of soil moisture storage and plant uptake of moisture to minimize or eliminate infiltration through the cover. ET covers offer performance and longevity advantages over traditional cover designs and have been gaining widespread acceptance in the semi-arid western U.S. as implementation of the technology expands and performance data accumulate. The ET cover modeling and conceptual design project was completed by Daniel B. Stephens & Associates, Inc. (DBS&A) under contract to Kaiser-Hill, LLC (KH).

The purpose of the ET cover modeling and conceptual design project is to develop a final cover design that considers both local conditions and economic factors to facilitate final design and construction. The ET cover must achieve regulatory compliance with Attachment 10 of the Rocky Flats Cleanup Agreement (RFCA) and achieve the best possible performance related project goals, which include:

- Minimized surface infiltration through the cover to levels that equal or outperform standard regulatory designs
- Regulatory compliance
- Meeting data quality objectives
- Best cover design for site-specific climate, soils, and vegetation
- Design integrated with overall RFETS closure configuration
- Sustainable vegetation and minimal erosion
- Maximized design life with minimal long-term care
- Design that contributes to surface water, groundwater, and air quality objectives
- Protection of wetlands and endangered species habitat
- Design that is soundly engineered, constructible, and cost-effective
- Support for RFETS environmental restoration objectives for site closure

This Conceptual Design Report presents the results of modeling completed to demonstrate ET cover performance and the conceptual engineering design. The modeling and conceptual design approach and results are briefly described in the following sections.

Design Criteria

Design criteria for the conceptual design process were formulated by compiling pertinent regulations, industry standards, and engineering judgments to ensure proper design of a successful ET cover. The design criteria found in this report are compatible with RFCA Attachment 10 requirements and RFETS project objectives. The design criteria include both functional and regulatory requirements used as the basis for the conceptual design. The design criteria include both the minimum requirements that must be achieved by the ET cover conceptual design as well as more stringent requirements that have been identified as requirements to meet RFETS objectives for final closure of the Present Landfill.

Performance Modeling

Performance modeling has been undertaken to support the conceptual design and to demonstrate the performance of ET covers with respect to minimizing infiltration through the cover. Water balance modeling must demonstrate that the ET cover thickness and water-holding capacity characteristics will provide for infiltration reduction performance equivalent to that of a more conventional cover design. The UNSAT-H model was used to compare the ET cover's effectiveness using inputs representative of site-specific soils, climate, and vegetation. The UNSAT-H results indicate that infiltration through the ET cover will be nearly zero.

Conceptual Design

Conceptual engineering design plans were prepared to show the cover system components and configuration. The ET cover consists of the following components:

- Erosion protection layer
- Soil-rooting medium

- Geotextile separation fabric
- Landfill gas-venting layer

The materials used for the ET cover consist of native, earthen materials, which are not subject to degradation. The only synthetic materials used in the cover are for the landfill gas-venting system, which requires longevity of approximately 25 to 75 years, until the landfill gas generation potential is nearly exhausted. The ET cover conceptual design provides for gentle slopes of 3 to 14 percent to provide slope stability and minimize storm water runoff and erosion.

Borrow Soil

Many potential sources of borrow soil and rock materials exist, including both off-site commercial quarries and on-site borrow areas at RFETS. Optimization of the ET cover in final design will require additional evaluation of the source availability, layer thicknesses and overall suitability of the cover components.

Vegetation

Revegetation of the ET covers with native species will provide infiltration reduction and erosion control, assurance of longevity, and compatibility with the surrounding environment. This approach is in keeping with the current revegetation strategy at RFETS to restore the native prairie grasslands as closely as possible to preexisting conditions.

Erosion Control

Performance of the conceptual cover design after 1,000 years of erosion was evaluated using the RUSLE model. RUSLE results are consistent with on-site observations at RFETS, which show stable, well-developed soil horizons on nearby native slopes similar to slopes in the proposed conceptual design.

The erosion protection layer will specify a significant fraction of rock and gravel-sized particles to resist both storm water and wind erosion. The required thickness of the erosion protection layer will vary, with an overall 6-inch minimum thickness, and a maximum 12-inch thickness on steeper side slopes.

Storm Water Management Plan

To meet the design criterion for longevity, storm water control is achieved by dispersed, overland flow without the use of storm water channels that focus erosive forces. The ET cover design provides runoff characteristics that are similar to undisturbed, native areas at RFETS. The storm water management plan for the Present Landfill can handle intense storm events with minimal runoff and little impact to surrounding areas or the site-wide surface control system at RFETS. This design approach reduces runoff and maintenance to the extent possible.

Performance Monitoring Plan

A performance monitoring plan will be implemented to demonstrate the ET cover's compliance with regulatory standards. The monitoring plan provides a phased approach with more intensive monitoring in early years during vegetative establishment and eventual cessation of monitoring activities when performance is proven. During Phase I intensive monitoring, an understanding of the cover water balance and performance will be established. Phase II will link visual observations of vegetation to the cover water balance through water potential monitoring and numerical modeling. Phase III, if needed, will continue system performance monitoring, maintenance, and vegetation monitoring for an extended duration. The monitoring plan details the monitoring instrumentation and procedures needed to demonstrate ET cover performance.

Operation and Maintenance

Post-closure operation and maintenance of the landfill cover will require vegetation establishment, performance monitoring, and long-term operation and maintenance. The operation and maintenance requirements will be more intensive during the first years after construction of the ET cover. Monitoring intensity will decrease over time as understanding of cover performance increases. Little long-term maintenance is expected after vegetation is established. Periodic maintenance of the gas vents will be needed during the operational life of the gas-venting system. When gas generation rates have declined to a level at which the venting system is no longer needed the gas vents may be removed.

Constructibility

The conceptual design of the Present Landfill ET cover provides for practical construction methods. The earthwork, aggregate placement, piping installation, geosynthetics installation, and revegetation associated with construction of the cover are standard in the U.S. construction industry. Construction methods will vary depending on whether on-site or off-site soil borrow sources are selected, both of which are feasible options. On-site borrow will require excavation and processing to screen rock and aggregate materials. Off-site borrow will require that suitable haul routes be established to transport materials from commercial quarries.

Schedule

The schedule for construction of the ET cover is expected to take 8 to 10 months to complete. The entire project including final engineering design, contractor selection, and construction certification should be completed in approximately 24 months. The 2-year Present Landfill project schedule does not include the current review and regulatory approval process, since the approval process is linked to many other projects, issues, and decisions in the overall site-wide RFETS closure.

Material Quantities

Basic requirements for material properties, layer thicknesses, gas-venting system, and ET apron layout were planned using reasonable assumptions and dimensions. Material quantities for cover construction were calculated based on the ET cover conceptual design. Various design options were examined that affect material quantities substantially. Two cover grading plan options were considered, one of which assumes in-place closure of the asbestos disposal areas, and the other relocation of asbestos waste. Design of the ET apron is also dependent on final disposition of the asbestos, with different excavation quantities required for the two closure options. The ET apron size and configuration may be optimized to achieve a soil balance.

Thus, the conceptual design approach incorporates a built-in mechanism to optimize the final design with regard to quantities and costs. Further engineering design refinement and optimization will be needed to reach the final design stage.

Cost Estimate

The project cost for engineering and construction of the Present Landfill ET cover is estimated to be approximately $10.2 to 11.2 million. In addition, long-term monitoring and maintenance is expected to cost approximately $650,000. These cost projections are for direct engineering, construction, and monitoring costs, and do not include the regulatory permitting process currently underway. This cost estimate provides preliminary budgetary planning information to assist RFETS decisions on implementing the ET cover approach.

Design and Cost Variables

The conceptual design of the Present Landfill ET cover is based on available information, which was sufficient to complete the conceptual level (Title I) design. Certain design and cost variables will need to be addressed in more detail for the final (Title II) design. Critical variables identified include:

- Site-specific data on borrow materials are needed for final design. After a final determination of the soil borrow source location is made, a geotechnical investigation is needed to evaluate soil properties for final design calculations.

- The cover design is closely linked to groundwater conditions to determine slope stability and seepage control. Based on RFCA Attachment 10 performance standards, the performance of the Present Landfill will depend on a combination of cover performance and groundwater control measures. Final design of the ET cover must be completed in conjunction with the overall plans for final closure of the Present Landfill.

- Information on existing methane vents, rationale for their installation, construction details, and landfill gas quality should be reviewed. This information was not available for this report and could affect the final design of the venting layer.

- The cost for asbestos relocation is the single most important cost variable and hinges on very incomplete records of the quantity and location of asbestos materials. Before proceeding with final design, additional research on the asbestos waste disposal is recommended based on available records and/or knowledge of RFETS personnel and possible site investigation.

Feasibility Analyses

Feasibility of an ET cover for the Present Landfill was analyzed with regard to many criteria including site characteristics, modeling results, long-term effectiveness, and cost. The conceptual design project has evaluated all the traditional engineering aspects of the proposed closure of the Present Landfill and produced reasonable results and conclusions. Based on the results, an ET cover is recommended as the closure method at the Present Landfill.

The feasibility analyses are presented in a separate feasibility report included as Appendix B. The site characteristics needed to implement a viable ET cover are all present at the RFETS site. Climatic conditions are favorable since RFETS is located in an area with low precipitation and has dry conditions that contribute to high potential evaporation. Modeling shows that the proposed 2-foot-thick ET cover is equivalent to a conventional cover.

Recommendations

The ET cover is practical, constructible, and affordable, and has advantages over conventional cover designs. The conceptual design is intended to provide sufficient design and performance information for a decision on whether to include an ET cover as a component of the final decision document for Present Landfill closure. ET cover feasibility must be considered in conjunction with other aspects of Present Landfill final closure plans, which include groundwater control, surface water quality, air emissions, and restoration of vegetation. The Present Landfill closure design must be compatible with overall RFETS site-wide restoration objectives.

ET covers are a relatively young and innovative technology; yet the body of scientific evidence demonstrating the successful performance of ET covers continues to grow. In semi-arid climates in the western U.S., ET covers utilize the natural processes of soil-moisture storage and plant uptake of moisture to provide infiltration reduction. Performance modeling of the Present Landfill ET cover, using site-specific input parameters, demonstrates that the ET cover can provide equivalent performance.

Based on the results of the conceptual design evaluation, the final design and implementation of an ET cover should proceed for final closure of the Present Landfill. The ET cover design approach can provide a solution to the combined performance requirements of infiltration reduction and longevity that is equivalent to or exceeds conventional cover designs. The ET cover can be monitored in the short term to prove its performance, and then be released from continued maintenance in the long term.

1. Introduction

This report, *Conceptual Design for the Present Landfill, Rocky Flats Environmental Technology Site* (Conceptual Design Report) presents the preliminary design basis and performance justification for a final cover planned for the Present Landfill at the Rocky Flats Environmental Technology Site (RFETS). The planned final cover is an evapotranspiration (ET) cover, which offers performance and longevity advantages over traditional cover designs for this site. This Conceptual Design Report presents the results of preliminary conceptual design efforts for the Present Landfill ET cover.

Daniel B. Stephens & Associates, Inc. (DBS&A) was contracted by Kaiser-Hill, LLC (KH) to complete the conceptual design for an ET cover at the Present Landfill. The project is being conducted in accordance with the Statement of Work prepared by KH (Revision D, February 2001).

As the first major project milestone, DBS&A submitted a draft work plan on July 23, 2001 (*DBS&A, 2001a)*. This report was revised and resubmitted on November 16, 2001 (DBS&A, 2001b). The ET cover performance modeling and conceptual design have been developed in accordance with this work plan, and this Conceptual Design Report represents the final project milestone of the conceptual design phase of the project.

Performance modeling was undertaken to support the conceptual design and to demonstrate the performance of ET covers with respect to minimizing infiltration through the cover. The performance modeling approach and results are also included in Appendix A of this Conceptual Design Report. The modeling results demonstrate that an ET cover for the Present Landfill can provide performance adequate to meet RFCA Attachment 10 requirements.

This Conceptual Design Report is organized in the following manner:

- Introduction, including project goals, site history, and regulatory status
- Design criteria
- Conceptual engineering design
- Vegetation plan

- Erosion control
- Storm water management plan
- Monitoring plan
- Constructibility evaluation
- Cost estimate
- Summary and conclusions

The Conceptual Design Report presents the technical and engineering basis for the ET cover design to KH, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA) Region VIII, and the Colorado Department of Public Health and Environment (CDPHE). The Conceptual Design Report is intended to provide these RFETS decision-makers with initial information regarding ET cover performance and implementation costs that will facilitate decisions on whether the ET cover approach is feasible and should be pursued. The feasibility of the ET cover approach is discussed in the Feasibility Report provided in Appendix B.

1.1 Project Goals

The purpose of the ET cover modeling and conceptual design project is to develop a final cover design for the Present Landfill. The ET cover must achieve regulatory compliance with Attachment 10 of the RFCA and achieve the best possible performance related to a number of goals. These technical goals include:

- Minimized surface infiltration through the cover to levels that equal or outperform standard regulatory designs
- Regulatory compliance
- Meeting data quality objectives
- Best cover design for site-specific climate, soils, and vegetation
- Design integrated with overall RFETS closure configuration
- Sustainable vegetation and minimal erosion
- Maximized design life with minimal long-term care
- Design that contributes to surface water, groundwater, and air quality objectives
- Protection of wetlands and endangered species habitat

- Design that is soundly engineered, constructible, and cost-effective
- Support for RFETS environmental restoration objectives for site closure

These goals are reflected in the design criteria presented in Section 2.

1.2 Site Description

The Present Landfill location is shown on the RFETS Site Map in Figure 1. The Present Landfill consists of a waste disposal area of approximately 21 acres with an additional 9 acres of buttress and pond. A landfill site plan is provided in Figure 2.

1.2.1 History

The Present Landfill was operated as a municipal landfill, receiving waste from Rocky Flats facilities from 1968 through 1998. Waste disposal records indicate that the landfill contains approximately 400,000 cubic yards (cy) of waste. The landfill contains primarily municipal and industrial solid waste, and has received some sludge and hazardous waste.

The Present Landfill currently has an interim soil cover over the entire site. Available records provide no details indicating the thickness of the interim soil cover, which was likely constructed in phases at various times over the life of the facility. Cover slopes range from relatively flat to maximums of approximately 7 percent on the landfill "top deck" or "crown" and approximately 30 percent on the eastern side slope. The cover has been seeded and vegetation is becoming established. Passive landfill gas vents have been installed in the interim cover.

Considerable progress has been made in development of a final closure strategy for the Present Landfill. Much of the previous work is compiled in Phase I IM/IRA Decision Document and Closure Plan for Operable Unit 7, Present Landfill (DOE, 1996). This work addresses not only cover design but also groundwater control, surface water quality, and air quality issues.

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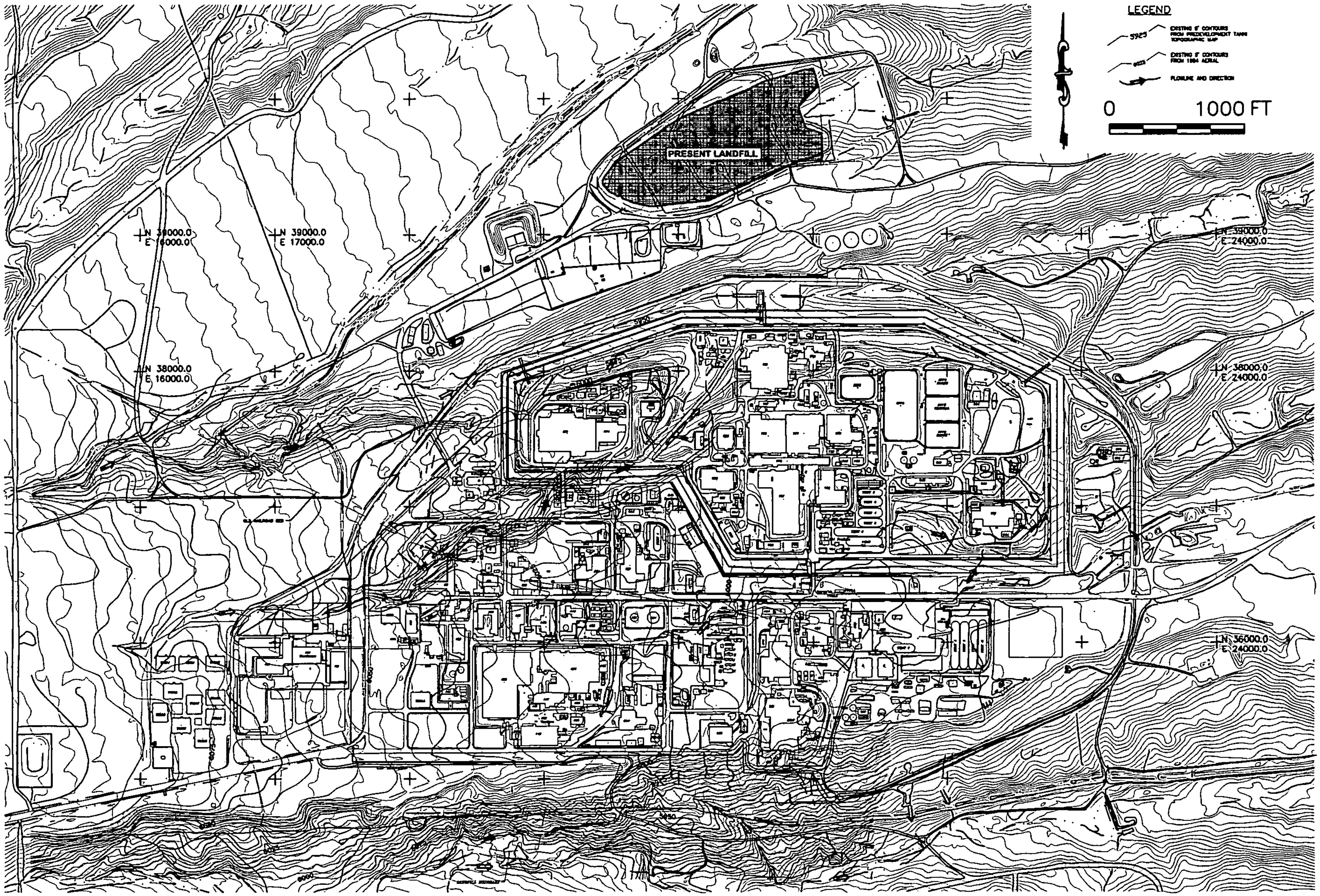

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Present Landfill Site Location Map

Figure 1

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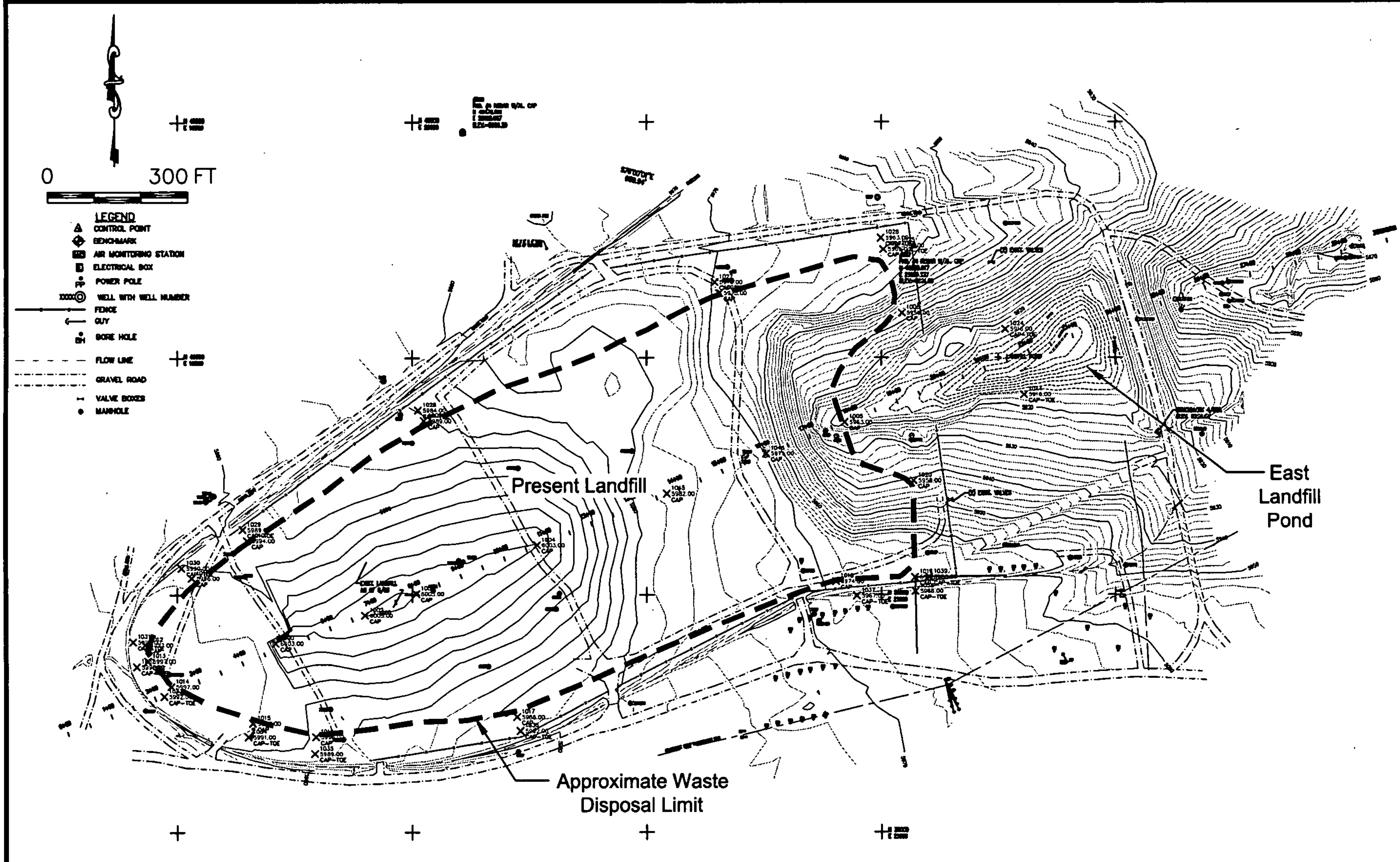

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Present Landfill Site Plan

Figure 2

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1.2.2 Regulatory Status

The Present Landfill is a Resource Conservation and Recovery Act (RCRA) Subtitle C interim status unit to be closed under the provisions of Attachment 10 to RFCA. The most significant RFCA compliance issues are related to the quality of shallow groundwater and surface water at the eastern, downgradient end of the landfill. A seep at the toe of the eastern landfill slope discharges an average of about 2-3 gallons per minute through a passive aeration treatment system into the East Landfill Pond (Figure 2). Near the East Landfill Pond, slumping of native soils has occurred due to shallow seeps. To the east of the landfill, No Name Gulch receives inflow from shallow seeps and from storm water diversion channels that route surface water around the landfill. In accordance with RFCA, downgradient and downstream points of compliance need to be established.

2. Design Criteria

Design criteria for the conceptual design process were established as part of the project work plan (DBS&A, 2001b). Design criteria for the Present Landfill were formulated by compiling pertinent regulations, industry standards, and engineering judgments that will ensure proper design of a successful ET cover. The design criteria found in this report are compatible with RFETS project objectives and will serve to enhance closure of the site. Table 1 summarizes the design criteria for the ET cover conceptual design.

The design criteria are the functional requirements used as the basis for the conceptual design. Many of the design criteria are specific requirements while others are objectives that will require further analysis. The design criteria presented in this section include both the minimum requirements that must be achieved by the ET cover conceptual design as well as more stringent requirements that have been identified as requirements to meet RFETS objectives for final closure of the Present Landfill.

2.1 Alternative Cover Performance and Regulatory Compliance

The primary regulatory consideration for ET cover approval is to demonstrate that the cover will meet RFCA Attachment 10 requirements. Conventional cover designs have significant drawbacks in meeting these requirements at the Present Landfill: (1) synthetic flexible membrane liners (FMLs) have an uncertain longevity and may not achieve the desired design life and (2) compacted clay covers desiccate and crack in semi-arid conditions.

ET cover designs have been undergoing technical development and have been gaining more widespread regulatory acceptance in recent years. ET cover applications have included both hazardous waste landfills (RCRA Subtitle C) and municipal landfills (RCRA Subtitle D). For example, Landfills 5 and 6 at Fort Carson, which were approved by CDPHE, were designed to meet Subtitle C requirements (Earth Tech Environment and Infrastructure, Inc., 2000). A number of field studies have provided data substantiating the performance of ET covers, and these long-term studies are ongoing. Many of these projects have been conducted in

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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
Rocky Flats Environmental Technology Site
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Subject Area	Design Criteria
Water Balance Modeling Criteria	
Evapotranspiration performance criteria	The ET cover will be designed to be equivalent to a conventional cover design consisting of a flexible membrane liner (FML) and a 2-foot thick clay barrier layer.
Design climatic data/storm event scenarios	Climate input is hourly data from a 48-year precipitation record from Stapleton Airport (Denver, Colorado). Precipitation data for the wettest 1-year, 3-year, and 5-year periods will be input into the model and repeated as necessary to determine long term performance of the covers. Snowmelt will be predicted using the Restricted Degree-Day Radiation Balance Approach using an A_r factor of 0.25.
Vegetation parameters	Average percent of bare soil will be a minimum of 5%. Rooting density functions assume that 80% of root mass occurs in upper 1 foot of cover (AA=0.8705, B1=0.06108, and B2=0.0144). Wilting suction head (HW) is 20,000 cm, root-soil water potential inflection point (HD) is 3,000 cm, anaerobic conditions suction head (HN) is set at 1 cm.
van Genuchten parameters	Alpha = 0.0438, N = 1.37, residual moisture content (θ_r) = 0.11, and saturated moisture content (θ_s) = 0.38.
Cover Soil Properties	
Texture/description [a]	ASTM Soil Classification = clayey sand with gravel. USDA Soil Classification = sandy loam.
Atterberg limits [a]	Liquid limit = 33%, plastic limit 21%, plasticity index = 12%
Particle size distribution [a]	Median particle diameter (d50) = 0.70 mm, uniformity coefficient (cu) = 226 mm, coefficient of curvature (cc) = 8.3 mm, mean particle diameter = 1.9 mm, percent passing No. 4 sieve = 83 percent, percent passing No. 200 sieve = 19 percent.
Density [a]	Dry bulk = 1.63 g/cm^3 (102 pounds per cubic foot [pcf]), wet bulk = 1.76 g/cm^3 (110 pcf)
Calculated porosity [a]	38.6% Volume.
Saturated hydraulic conductivity (K_{sat}) [a]	5.1 x 10^{-4} cm/s.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

ET = Evapotranspiration
USDA = U.S. Department of Agriculture
g/cm^3 = grams per cubic centimeter
cm = centimeters
mm = millimeters
cm/s = centimeters per second
ASTM = American Society for Testing and Materials
NPDES = National Pollutant Discharge Elimination System

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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
Rocky Flats Environmental Technology Site

Subject Area	Design Criteria
Surface Vegetation Provisions	
Type of vegetation	Only native grasses and forbs will be used such as western wheatgrass, green needle grass, native grama and bluestem grasses.
Drought and temperature tolerance	Locally adapted native vegetation can withstand the precipitation and temperature extremes of the area.
Plant rooting	Vegetation shall be able to grow to a depth equaling the full thickness of the ET cover, which will be no less than 3 feet. Root density function parameters: AA=0.8705, B1=0.06108, B2=0.0144.
Ability to thrive in on-site soils	Locally adapted native vegetation can thrive in on-site soils with little maintenance.
Transpiration characteristics	Cool and warm season species will be specified to provide transpiration throughout as much of the year as possible. Locally adapted species of grasses and forbs will transpire all available water in a semiarid climate.
Erosion resistance	Vegetation will assist in limiting cover erosion to less than 2 tons/acre/year.
Erosion Resistance and Storm Water Control	
Storm water parameters and controls	All run-off controls will be designed for a 100-year, 24-hour storm event and implemented in accordance with NPDES standards.
Surface erosional resistance/tolerance	2 tons/acre/year. Allowable erosion must also meet design life criteria.
Minimum and maximum slopes	Minimum = 3%, maximum = 14%.
Run-on controls	All run-on controls will be designed for a 100-year, 24-hour storm event.
Slope Stability	
Slope stability tolerances	Static factor of safety = 1.5, Dynamic factor of safety = 1.3.
Design Life	
Design life period	1,000 years
Subsidence Tolerance and Resistance (Landfill Specific)	
Subsidence criteria	The grading plan will be designed to ensure positive drainage of post-closure settlement grades.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

ET = Evapotranspiration
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g/cm^3 = grams per cubic centimeter
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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
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Subject Area	Design Criteria
Landfill Gas and Passive Vent System Criteria (Landfill Specific)	
ET cover landfill gas conditions	The full thickness of the cover will not contain high levels of methane and will possess appropriate levels of oxygen for healthy root growth.
Vent layer	Cobbles, gravel, or approved material meeting approved gradation specifications, with a minimum thickness of 6 inches and a particle diameter no less than 0.5 inch.
Vent well	Vent wells will be constructed of DR-17 high density polyethylene (HDPE) or other suitable materials with a minimum diameter of 2 inches.
Miscellaneous specifications	The vent layer will be designed to provide for the safe collection and venting of landfill gases without danger of explosion. The vent layer should also be able to resist biofouling, prevent infiltration, and withstand settlement.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

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USDA = U.S. Department of Agriculture
g/cm^3 = grams per cubic centimeter
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association with EPA's Alternative Cover Assessment Program (ACAP). Additional details on ACAP are provided in Appendix C.

2.1.1 Alternate Cover Acceptance in the Western U.S.

Alternative cover performance standards and requirements vary greatly across the western U.S. Performance standards from other states with similar semi-arid climates provide some design guidance to evaluate ET cover performance. California standards for equivalence are site-specific and have allowed up to 1 inch per year (inch/yr) percolation. Utah will soon permit a site where equivalent performance allows up to 8 centimeters (3 inches) of percolation. New Mexico defines equivalent covers as those that are within an order of magnitude percolation of the conventional cap at the low percolation values often obtained. (For example, since percolation values for conventional covers are often 0.01 inch/yr or less, New Mexico would define an equivalent cover as one with percolation of 0.1 inch/yr or less.) Arizona sites can meet the equivalence criterion by demonstrating upward flux using numerical models. Nebraska will soon examine existing local ACAP data from Omaha and likely make a decision to approve a nearby alternative cover based upon qualitative evaluation of the data (Appendix C).

2.1.2 Performance Requirements for RFETS ET

The ET cover must be designed to control, minimize, or eliminate, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste decomposition products to the ground or surface waters or to the atmosphere. The cover will be compatible and support all site-wide objectives, regulations, and agreements including all applicable or relevant and appropriate requirements (ARARs). Attachment 10 of RFCA requires that the final cover over the Present Landfill limit infiltration to the extent necessary to prevent continued contaminant impacts that will contribute to the spread or increased concentration of groundwater contaminants.

2.2 Water Balance Modeling Criteria

In addition to meeting RFCA Attachment 10 requirements, ET cover performance was also compared to more standard cover designs. The model selected for this comparison was UNSAT-H (see Appendix D for information about model selection). The comparison demonstrated the ET cover performed similarly to a conventional cover design. Field monitoring during the post-closure care period will be conducted to demonstrate performance. The conceptual design included a water balance modeling effort, which is presented in detail in Appendix A.

2.2.1 Model Input

UNSAT-H uses numerous input parameters, some of which are straightforward (such as site elevation and height of the wind velocity measurements) or have standard values. The more important site-specific parameters such as soil, climatological, and vegetative parameters and/or data inputs are detailed below. Table 2 summarizes the sources of input data for UNSAT-H modeling of the ET cover.

2.2.2 Climatological Parameters

Fairly complete climatological data are available from the Denver Stapleton Airport, where these data have been collected since the late 1940s. Individual precipitation events vary between the airport and RFETS, but long-term trends, variability, and averages are similar. Therefore, climatological data collected from Stapleton Airport were used as input for UNSAT-H modeling of RFETS ET cover. To provide a conservative analysis and account for the somewhat higher precipitation at RFETS, years of high precipitation were selected from Stapleton's climatological record for the modeling analysis.

Climatological data were used that simulated the historic conditions most likely to produce recharge through soil cover. Two time periods for simulation were selected based on an investigation of the 48-year precipitation record at Stapleton Airport. Precipitation during the winter and early spring of 1982 to 1983 was greater than for any similar period of record, and

Table 2. Sources of UNSAT-H Climatological, Vegetation, and Soil Parameters

Input Parameter	Source
Climatological Data	
Precipitation	Denver Airport National Climatic Data Center (NCDC) primary weather station (WBAN #23062)
Temperature	Denver Airport NCDC primary weather station (WBAN #23062)
Dew point	Calculated from temperature and relative humidity, the latter of which was taken from NCDC primary weather station at Denver, Colorado (WBAN #23062)
Solar radiation	Denver Airport NCDC primary weather station (WBAN #23062)
Wind speed	NCDC primary weather station at Denver, Colorado (WBAN #23062)
Cloud cover	NCDC primary weather station at Denver, Colorado (WBAN #23062)
Plant Data	
Leaf area index	Pawnee Grasslands data
Rooting depth	Borrow site observations, soil gas data
Rooting density	Root density function AA=0.8705, B1=0.06108, B2=0.0144 (same parameters as at RMA)
Soil Data	
Cover material hydrologic characteristics	DBS&A laboratory data from LaFarge Quarry sample
Number of layers	Multiple layer systems

WBAN = Weather Bureau, Army, and Navy RMA = Rocky Mountain Arsenal the wettest 1-year, 3-year, and 5-year periods of record are all within the 1965 to 1969 period. Therefore, a 7-year sequence including both of these extreme periods was developed for model input. The series 1982, 1983, 1965, 1966, 1967, 1968, and 1969 were modeled sequentially after first simulating an additional 1982 period to initialize the model. This 7-year period was iterated to determine long-term performance of the cover.

Data from Stapleton Airport will not reflect known differences in wind speed and decrease in solar radiation due to Rocky Flats proximity to the mountains. Both of these factors affect the water balance calculated by UNSAT-H. The stronger winds found at Rocky Flats will increase evaporation and transpiration, while reduced solar radiation in late afternoons will reduce evaporation and transpiration. Both wind speed and solar radiation interact with slope aspect. The decrease in solar radiation due to the mountains will be smaller than differences seen between natural or engineered north and south slopes. The west-facing slopes that may be most affected by reduced evening solar radiation will receive the largest 'benefit' of increased drying from down-canyon winds.

2.2.3 Vegetation Parameters

UNSAT-H requires the input of various parameters for use in predicting the amount of evapotranspiration from the soil profile. One important set of vegetative parameters describes the leaf area index (LAI) distribution throughout the year. Modeling scenarios assumed a standard annual distribution of LAI and did not consider the initial several seasons of reduced LAI while vegetation is being established on the cover. The LAI was based on plant species in the planned RFETS seed mixture.

UNSAT-H linearly interpolates between the specified dates where the LAI is specified by the user. Dates for the last frost in the spring and the first frost in the fall were used, along with other site-specific knowledge related to the growing season at RFETS.

Based on studies conducted at the Rocky Mountain Arsenal (RMA) in Denver, the average percentage of bare soil for cool season and warm season dominated grassland areas are

5 percent and 2 percent, respectively (Morrison Knudsen, 1989). The more conservative value, 5 percent, was used for input to UNSAT-H in the RFETS scenarios.

UNSAT-H requires three parameters to describe the root density function. These parameters were determined by fitting an exponential curve (used by UNSAT-H) to data reported by Liang et al. (1989) for a grassland vegetation on clay/loam soils at the Pawnee Grasslands in northern Colorado. The three parameters are AA=0.8705, B1=0.06108, and B2=0.0144. For perspective, these coefficients cause UNSAT-H to calculate that 80 percent of the root length is in the upper 1 foot of soil. DBS&A requested input from the KH Ecology Group to verify that the root density function was reasonable for use at the RFETS. The specified maximum rooting depth was set equal to the thickness of the cover being modeled. Rooting depths in the borrow material area near the RFETS were observed to reach depths greater than 6 feet, indicating that native vegetation is expected to establish roots through the full thickness of the ET cover soil-rooting medium.

Initially, the suction head corresponding to the water content below which plants wilt and stop transpiring (HW in UNSAT-H) is set at 20,000 centimeters (cm) (almost 20 atmospheres). This value is similar to the in situ values measured in some RMA soil profiles (Fayer, 2000). The suction head corresponding to the water content below which plant transpiration starts to decrease, sometimes referred to as the root-soil-water potential inflection point (HD in UNSAT-H), is set at 3,000 cm based on information presented by Gardner (1983) for loam soils. The suction head corresponding to water content above which plants do not transpire because of anaerobic conditions (HN in UNSAT-H) is set at 1 cm.

2.2.4 Soil Parameters

An investigation was conducted to characterize, sample, and test the typical borrow soil available at RFETS for possible use in constructing the ET cover. Soil was sampled from the LaFarge Quarry adjacent to the northern RFETS boundary, where borrow soil may be obtained during cover construction. The soil is characterized as a sandy loam using the U.S. Department of Agriculture (USDA) Soil Classification and as a clayey sand with gravel using the American Society for Testing and Materials (ASTM) Soil Classification.

Laboratory analysis revealed the following soil characteristics:

- Calculated porosity of the soil is 38.6 percent by volume
- Dry bulk density of the material is 1.63 grams per cubic centimeter (g/cm^3)
- Saturated hydraulic conductivity is 5.1×10^{-4} centimeters per second (cm/s)
- van Genuchten parameters for this sample are:
  - $\alpha = 0.0438$
  - N = 1.37
  - residual moisture content (θ_r) = 0.11
  - saturated moisture content (θ_s) = 0.38

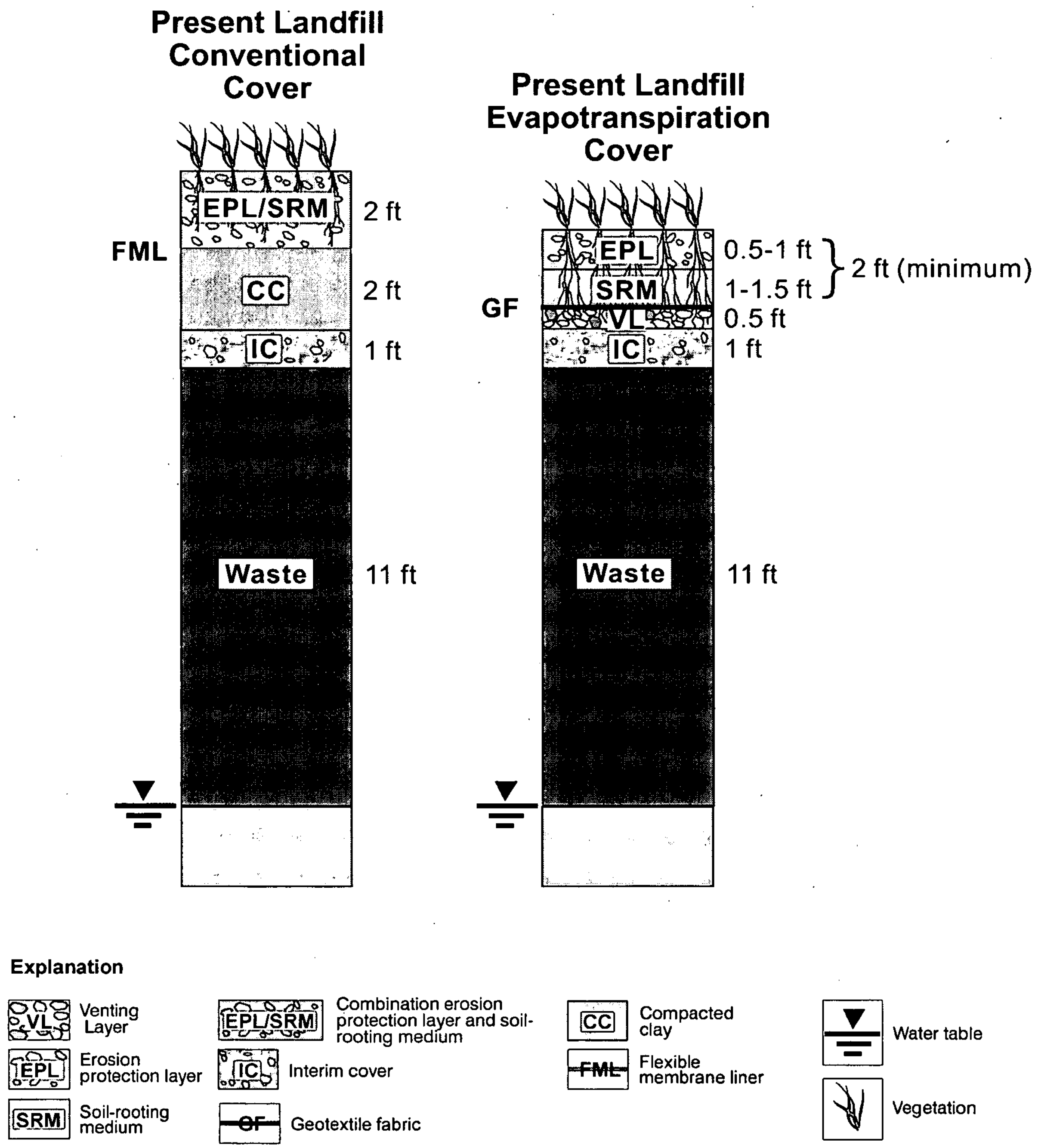
The soil data were input into UNSAT-H, using the van Genuchten function model option (van Genuchten, 1991). An albedo value of 0.2 was used for modeling (Houghton, 1985).

2.2.5 Model Layering

UNSAT-H can simulate systems made up of multiple layers with differing characteristics. The Present Landfill ET cover will be a multilayered system with the major component being a rooting medium soil layer consisting of borrow material with the characteristics described in the section above. Other layers that were characterized for the modeling effort include the erosion protection layer, landfill gas-venting layer, existing interim soil cover, and waste material (Figure 3). Input parameters will be estimated for these layers based on material properties from other sites such as RMA and typical municipal landfills.

2.3 Cover Soil Properties

Cover soil properties must provide sufficient moisture retention capacity to minimize infiltration and support vegetative growth. Critical soil properties include particle size distribution, Atterberg limits, saturated hydraulic conductivity (K_{sat}), texture, and nutrient concentrations. Other material requirements include erosion resistance, cost, and availability. The LaFarge Quarry located adjacent to RFETS has been identified by KH as a potential source of material



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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Modeled Cover Cross-Sections

Figure 3

for cover construction. The following data, based on DBS&A test results from the LaFarge Quarry soil, were used during the modeling/design process.

• Texture/Description:	ASTM Soil Classification = clayey sand with gravel USDA Soil Classification = sandy loam
• Atterberg Limits:	Liquid limit = 33 Plastic limit = 21 Plasticity index = 12
• Particle Size Distribution:	Median particle diameter (d_{50}) = 0.70 millimeters (mm) Uniformity coefficient, Cu = 226 Coefficient of curvature, Cc = 8.3 Mean particle diameter = 1.9 mm Percent passing No. 4 sieve (4.75 mm) = 83 percent Percent passing No. 200 sieve (0.075mm) = 19 percent
• Saturated Hydraulic Conductivity (K_{sat}):	5.1×10^{-4} cm/s
• Moisture Content:	Volumetric = 13.1 percent Gravimetric = 8.1 percent
• Density:	Dry bulk = 1.63 g/cm^3 Wet bulk = 1.76 g/cm^3
• Calculated Porosity:	38.6 percent by volume

These soils data are representative of typical borrow soils available for cover construction. Additional soils testing will be needed for the final design once a final borrow source is identified.

2.4 Surface Vegetation Provisions

The current revegetation strategy at RFETS is to restore the native prairie grasslands as closely as possible to pre-existing conditions. Therefore, only native prairie grass and forb seeds will be used for vegetating the ET cover.

The following plant properties are required to ensure healthy, productive, and long-term vegetative growth on the landfill cover:

- *Drought and temperature tolerance:* Locally adapted (native) plants have thrived in the RFETS area for thousands of years under local climatic conditions of temperature and precipitation extremes. These species have developed natural tolerances for local extremes, making them the most suitable choice for the ET cover.

- *Plant rooting:* Roots must establish to a depth of no less than 2 feet. Root density functions for UNSAT-H are specified in Section 2.2.3.

- *Ability to thrive in on-site soils with little or no maintenance:* Long term fertilization and nutrient supplements are not planned at this time; therefore, it is critical that vegetation be able to survive in the conditions of the on-site soil. Native grasses and forbs will be able to thrive with little maintenance. Soil amendments may be provided to supplement borrow material to establish initial vegetation on the cover.

- *Transpiration characteristics:* The ET cover design will use both cool and warm season species to provide transpiration throughout as much of the year as possible. Locally adapted species of grasses and forbs normally transpire all available water in a semi-arid climate such as that of the RFETS.

- *Seed mixture and availability:* The seed mixture will be designed on-site by the KH Ecology Group based on a series of annual vegetation reports, which contain monitoring results from the native plant communities in the Buffer Zone, as well as information on the results of previous revegetation projects at the RFETS. The seed mixture calls for a variety of vegetation rather than a single species for each season. This is important, because if growing conditions become difficult for one species other species may still be able to flourish and ensure continued erosion protection and transpiration. Examples of cool season vegetation include native western wheatgrass, green needle grass, and most forbs; warm season mixtures include native grama and bluestem grasses.

* *Erosion resistance:* Vegetation will assist in limiting cover erosion from both wind and water to less than the 2 tons/acre/year recommended by EPA (1989).

The vegetation implementation schedule will detail appropriate seeding, short-term fertilization, and irrigation times as well as any other significant activities required to ensure a stand of healthy grass on the cover. During cover revegetation, weeds must also be controlled. Irrigation may be used to establish initial vegetation on the cover as necessary.

2.5 Erosion Resistance and Storm Water Control

Surface water runoff at the Present Landfill will be controlled by grading the cover surface to shed water to surrounding areas. To allow for proper drainage of storm water and to prevent ponding and erosion, the following design criteria will be observed.

* Slopes will be designed with a steep enough grade to prevent ponding of storm water, but gentle enough to prevent excessive run-off velocity and optimize long-term erosion control. The minimum slope for the Present Landfill ET cover will be 3 percent. The maximum anticipated slope for the ET cover is 14 percent. Due to existing topography, a slope of less than 14 percent cannot be practicably achieved on the east side of the landfill. Engineered measures will be used to ensure the slope minimizes erosion/abrasion of the cover.

* Soil erosion will not exceed 2 tons/acre/year as recommended by the EPA (EPA, 1989). The Revised Universal Soil Loss Equation (RUSLE) will be used to estimate soil losses over a 1,000-year cover design lifetime.

* Storm water controls, including drainage channels, swales, ponds, etc., will be designed and constructed to hold or control the volume of water expected during a 100-year, 24-hour storm.

- Storm water and erosion controls to prevent soil loss from disturbed areas, excavations, haul roads, borrow areas, and any other areas where erosion develops due to construction activities will be implemented.

- Any necessary run-on control systems will be designed, constructed, operated, and maintained to be capable of preventing flow onto the landfill during peak discharge from a 100-year storm.

2.6 Wetlands Impacts

The cover and storm water control systems will be designed to avoid adverse impacts on existing wetlands. The cover profile will be designed to minimize the footprint of the cover, while also taking into account slope stability and erosion considerations. Wetlands location maps completed at RFETS will be used to determine jurisdictional wetland areas.

The creation of wetlands (possibly as a component of the ET apron) may be considered as a mitigation measure to offset any unavoidable wetlands impacts. The loss of jurisdictional wetlands resulting from cover construction will be mitigated as part of the RFETS site-wide wetlands bank. The wetlands mitigation criteria should be defined, with input from the regulatory agencies, prior to the final design phase.

2.7 Slope Stability

Slopes will be designed to the following specifications:

- Final slopes will not exceed 14 percent to promote stability.
- The minimum factor of safety (FOS) for slopes under static conditions is 1.5.
- The final cover must withstand the maximum horizontal acceleration in earthen materials. The minimum factor of safety for slopes under dynamic (seismic) conditions is 1.3.

2.8 Design Life

Since an ET cover is constructed of unconsolidated soil, it can accommodate differential settlement without damage or loss of integrity. ET covers are suitable to meet the RFETS closure objectives because the longevity of ET covers typically exceeds that of a conventional cover design. This is because an ET cover does not rely on synthetic components that may degrade over time. The longevity of the ET cover will be demonstrated by consideration of natural analogues through a study of soil morphology at the RFETS. Compliance with design life criteria will be based upon the permanence and longevity of natural soil horizons at the RFETS.

The ET cover will be designed with a minimum design life of 1,000 years to meet RFETS closure objectives. The ET cover will be constructed so that there should be no failure of the cover system during its design life as a result of either seismic forces resulting from the maximum credible earthquake or by total erosion based on 1,000-year calculations.

2.9 Constructibility

The ET cover will be designed for standard construction methods. Constructibility issues will be evaluated for all components of the design to ensure the cover can be properly built in an efficient and effective manner.

Construction Quality Assurance (CQA) inspections will be conducted during the construction of the cover to ensure proper construction practices typical of 40 CFR 264.226 and 303. The cover will be inspected periodically for overall uniformity, damage, and imperfections as well as level of compaction (EPA, 1993). The ET cover will be constructed in a manner that will limit compaction to 80 to 90 percent of Standard Proctor density (ASTM D698). This can be achieved by the use of tracked or low-weight wheeled vehicles in combination with the placement of thicker lifts. In the event any portions of the cover are compacted beyond 80 to 90 percent of Standard Proctor density, the area will be ripped to reduce soil density until it meets the specification. The specified soil densities are essential to cover effectiveness to permit optimum root growth and maximize water-holding capacity.

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2.10 Subsidence Tolerance and Resistance

The following design criteria will be observed to ensure the Present Landfill cover will withstand any settlement that occurs over the life of the cover:

- The cover will accommodate settling and subsidence experienced at landfills so that the cover's integrity is maintained.
- Slope design will ensure that total settlement experienced by the cover will provide positive drainage for post-waste settlement grades.
- The cover will be constructed of unconsolidated soil to accommodate differential settlement.
- Maintenance due to settlement will be minimized.
- Positive drainage will be maintained across the final cover.

2.11 Landfill Gas

The cover will be designed and constructed so that landfill gases will not adversely affect the overall performance of the landfill cover and that all components of the cover are compatible with landfill gas, including vegetation. The design must provide for growth of deep-rooted grasses and forbs. Typically, even low methane levels indicate minimal oxygen concentrations. Methane displaces oxygen in the subsurface and reacts with it to form carbon dioxide and water. As required, controls such as passive vents and vent layers will be designed to reduce landfill gas concentrations entering the ET cover.

A landfill gas-venting system will be used to prevent adverse impacts on the rooting depth of vegetation. Such a venting system would consist of a gravel, cobble or approved material (minimum diameter of 0.5 inches) layer with a minimum layer thickness of 6 inches overlain by a geosynthetic fabric layer to prevent soil intrusion. A geosynthetic fabric may be specified due to the short design life requirement of the vent system. Since significant landfill gas production will only occur over the next few decades, it is acceptable if the geosynthetic fabric degrades over time. Passive landfill gas vent wells (minimum diameter of 2 inches) that extend from the gravel layer to the surface would be installed within the gravel layer. The final thickness of the vent layer and the well density will be determined during the design process. The vent layer will be designed to provide for the safe collection and venting of landfill gases. The vent layer should also be able to resist biofouling, prevent infiltration, and withstand settlement.

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3. Conceptual Engineering Design

This section presents the ET cover conceptual design, including a description of the cover components and functions, controls for storm water and landfill gas, and means of ensuring slope stability. It also addresses various environmental concerns and the types and quantities of materials needed for cover construction.

Conceptual design drawings, including a site grading plan, cross-sections, and plan details are provided in Figures 4, 5, and 6. Figure 7 shows a three-dimensional view of the planned ET cover for the Present Landfill.

3.1 System Function

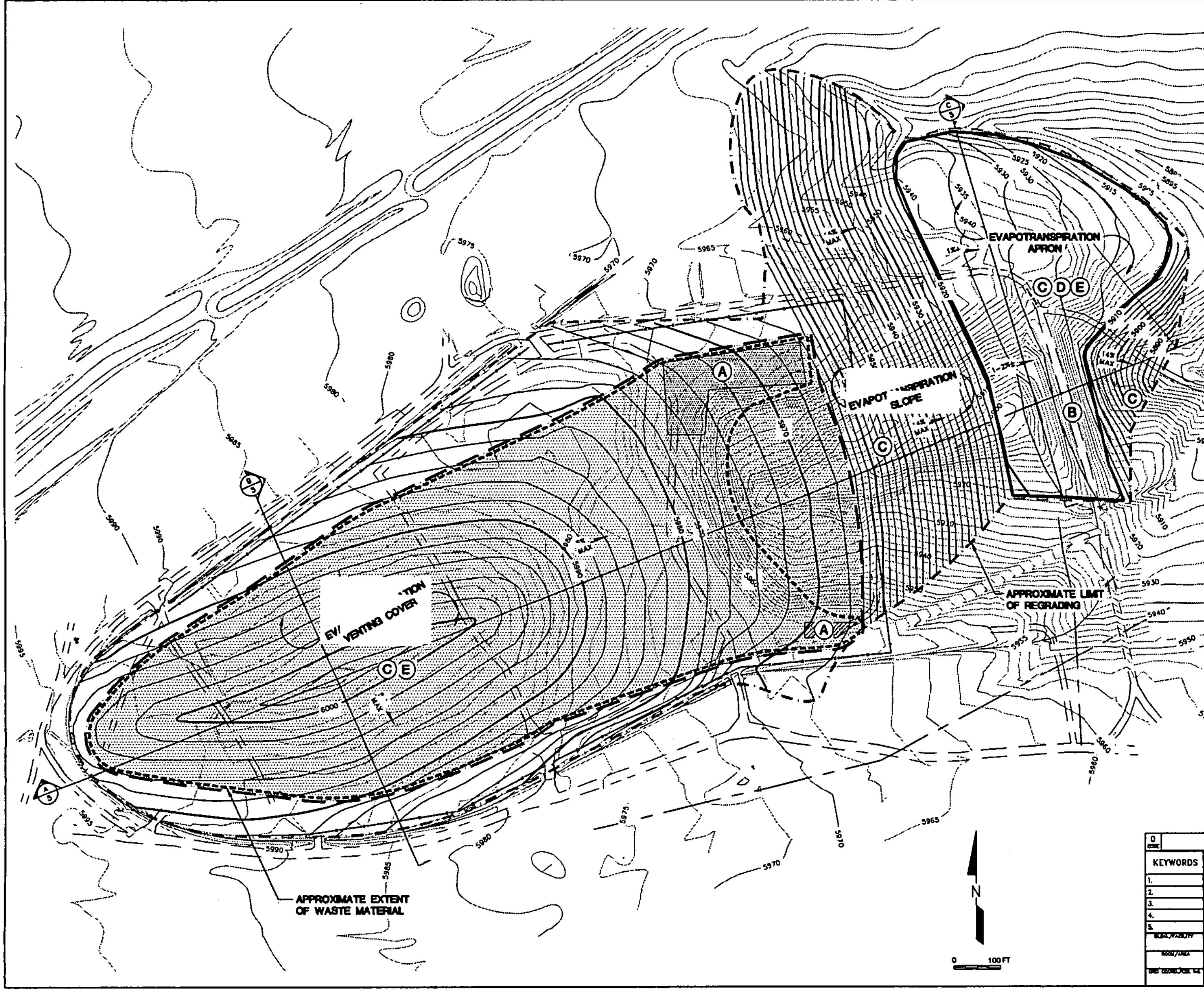
The ET cover planned for the Present Landfill must provide required performance in terms of infiltration reduction and erosion protection. ET covers generally consist of a uniform, monolithic soil layer, which achieves infiltration reduction performance through storage of soil moisture until removal of moisture through the natural processes of evaporation and plant transpiration. Establishment of sustainable vegetative communities is promoted, thereby minimizing wind and storm water erosion from the cover surface. The ET cover relies on natural processes to minimize infiltration through the cover, which has been demonstrated throughout the semi-arid western U.S. (Appendix C contains a summary of the current status and application of ET covers).

3.2 System Design Features

3.2.1 Evapotranspiration Modeling

ET cover performance can be modeled to provide a technical basis for the cover design. To model the ET cover, site-specific soil properties must be determined by laboratory testing and local climatic conditions must be considered. The design and performance modeling effort determines the soil thickness needed to provide sufficient capacity for soil moisture storage.

45



GENERAL NOTES:

1. THIS DESIGN IS BASED ON TOPOGRAPHIC INFORMATION PROVIDED BY OTHERS. THE ENGINEER CANNOT VALIDATE OR WARRANTY THIS INFORMATION.

DESIGN NOTES:

(A) EXISTING ASBESTOS DISPOSAL AREA.
(B) PORTION OF EXISTING EMBANKMENT TO BE REMOVED
(C) MAXIMUM SLOPE OF COVER SHALL BE 14%. MINIMUM SLOPE SHALL BE 3%.
(D) EVAPOTRANSPIRATION APRON PROVIDES BORROW SOIL SOURCE FOR COVER CONSTRUCTION AT PRESENT LANDFILL.
(E) SEE FIGURE 6 FOR EVAPOTRANSPIRATION COVER DETAILS.

LEGEND:

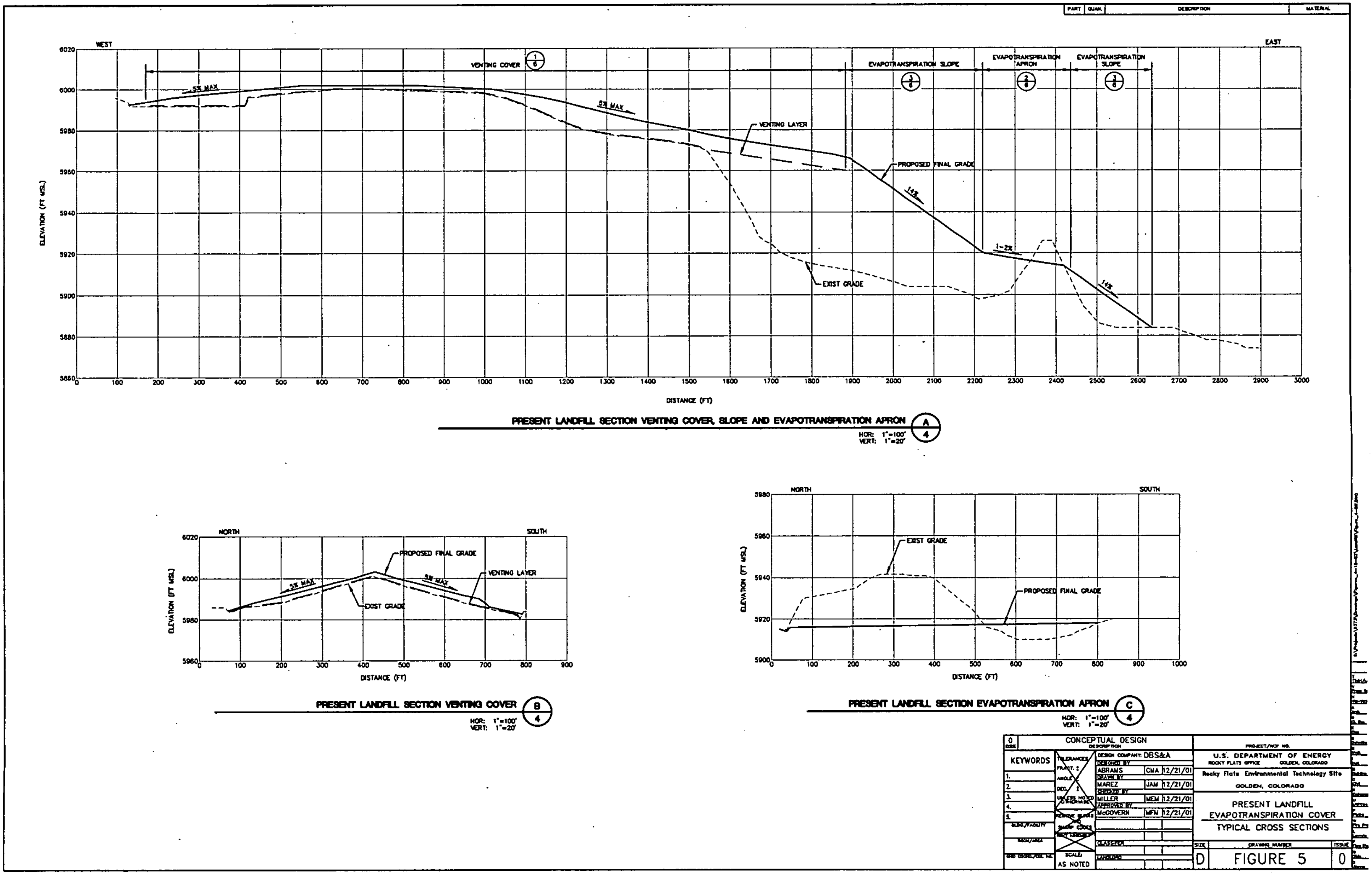
EXISTING GRADE CONTOURS
DESIGN GRADE CONTOURS
APPROXIMATE LIMIT OF REGRADING
APPROXIMATE EXTENT OF WASTE MATERIAL
APPROXIMATE LIMIT OF VENTING COVER

ISSUE	DESCRIPTION		
0	CONCEPTUAL DESIGN		
KEYWORDS	DESIGN COMPANY: DBS&A		
	DESIGNED BY ABRAMS	CMA	12/21/01
	DRAWN BY MAREZ	JAM	12/21/01
	CHECKED BY MILLER	MEM	12/21/01
	APPROVED BY McGOVERN	MFM	12/21/01
SCALE: 1"=100'			

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
PROPOSED GRADING PLAN

SIZE	DRAWING NUMBER	ISSUE
D	FIGURE 4	0



WEST
EAST
VENTING COVER
EVAPOTRANSPIRATION SLOPE
EVAPOTRANSPIRATION APRON
EVAPOTRANSPIRATION SLOPE
5% MAX
VENTING LAYER
PROPOSED FINAL GRADE
14%
1-2%
EXIST GRADE
ELEVATION (FT MSL)
DISTANCE (FT)
PRESENT LANDFILL SECTION VENTING COVER, SLOPE AND EVAPOTRANSPIRATION APRON
HOR: 1"=100'
VERT: 1"=20'
NORTH
SOUTH
PRESENT LANDFILL SECTION VENTING COVER
PRESENT LANDFILL SECTION EVAPOTRANSPIRATION APRON
CONCEPTUAL DESIGN
KEYWORDS
DESIGN COMPANY: DBS&A
ABRAMS CMA 12/21/01
MAREZ JAM 12/21/01
MILLER MEM 12/21/01
McGOVERN MFM 12/21/01
SCALE: AS NOTED
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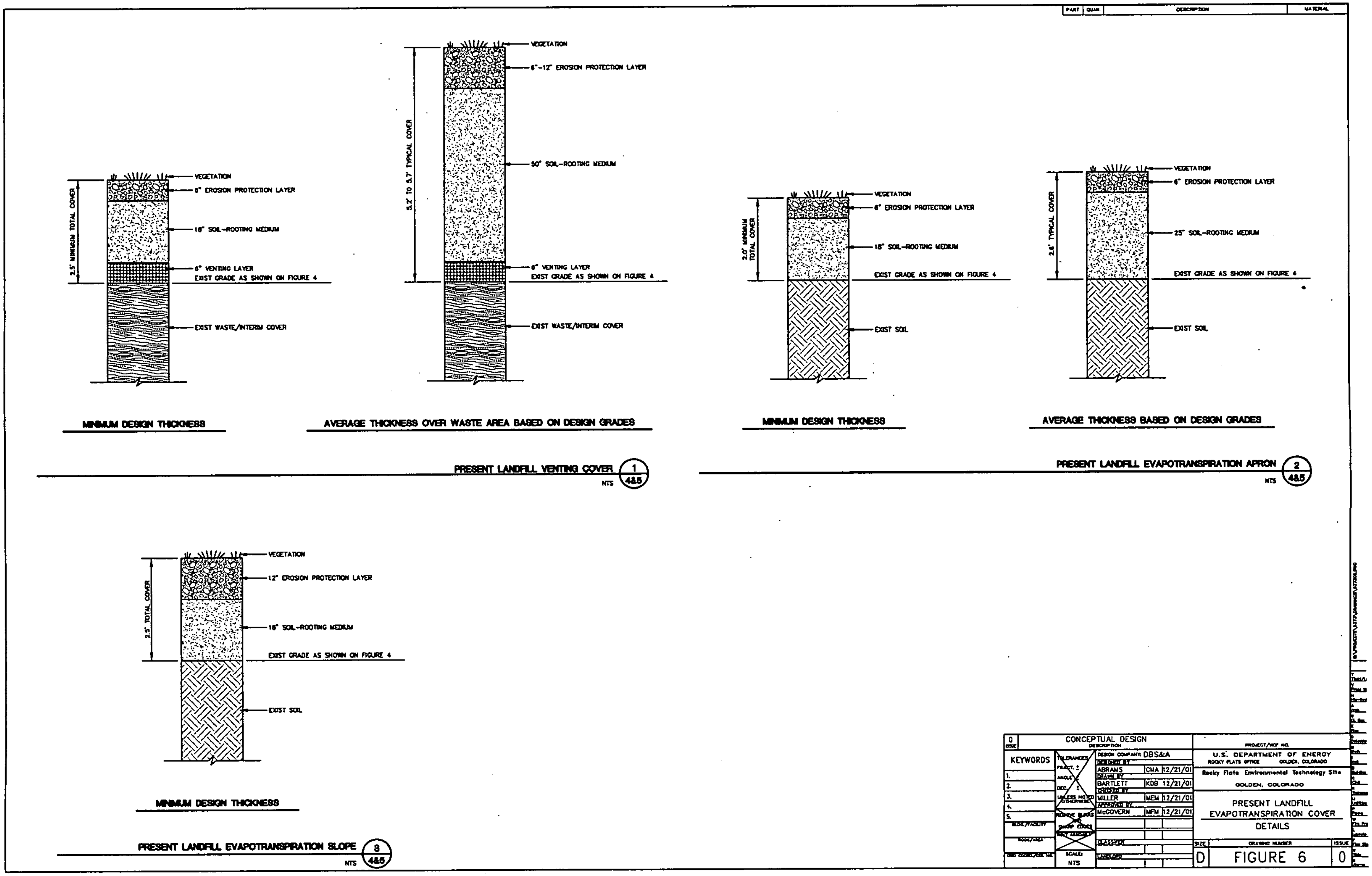
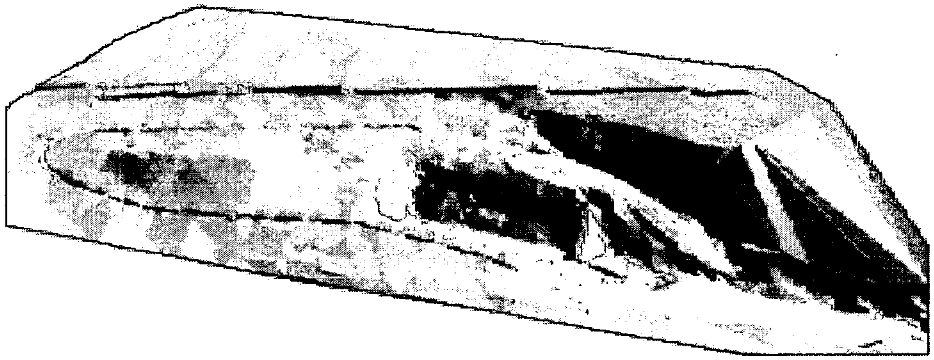
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
TYPICAL CROSS SECTIONS
D
FIGURE 5
0

46

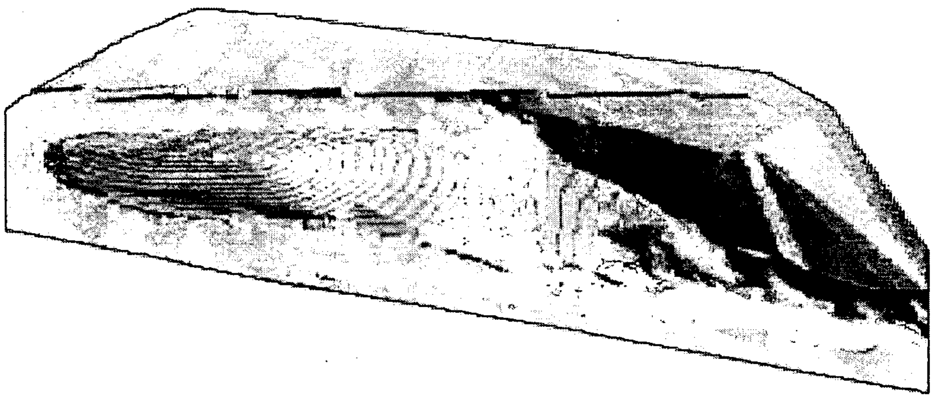
47


PART
QUAN.
DESCRIPTION
MATERIAL
VEGETATION
6" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
6" VENTING LAYER
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST WASTE/INTERIM COVER
2.5' MINIMUM TOTAL COVER
MINIMUM DESIGN THICKNESS
VEGETATION
6"-12" EROSION PROTECTION LAYER
50" SOIL-ROOTING MEDIUM
6" VENTING LAYER
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST WASTE/INTERIM COVER
5.2' TO 5.7' TYPICAL COVER
AVERAGE THICKNESS OVER WASTE AREA BASED ON DESIGN GRADES
PRESENT LANDFILL VENTING COVER
1
4&5
NTS
VEGETATION
6" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.0' MINIMUM TOTAL COVER
MINIMUM DESIGN THICKNESS
VEGETATION
6" EROSION PROTECTION LAYER
25" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.6' TYPICAL COVER
AVERAGE THICKNESS BASED ON DESIGN GRADES
PRESENT LANDFILL EVAPOTRANSPIRATION APRON
2
4&5
NTS
VEGETATION
12" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.5' TOTAL COVER
MINIMUM DESIGN THICKNESS
PRESENT LANDFILL EVAPOTRANSPIRATION SLOPE
3
4&5
NTS
0
ISSUE
CONCEPTUAL DESIGN
DESCRIPTION
PROJECT/WCF NO.
KEYWORDS
1.
2.
3.
4.
5.
TOLERANCES
FRACT. ±
ANGLE ±
DEC. ±
UNLESS NOTED OTHERWISE
SCALE:
NTS
DESIGN COMPANY: DBS&A
DESIGNED BY
ABRAMS CMA 12/21/01
DRAWN BY
BARTLETT KDB 12/21/01
CHECKED BY
MILLER MEM 12/21/01
APPROVED BY
McGOVERN MFM 12/21/01
CLASSIFICATION
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
DETAILS
SIZE
DRAWING NUMBER
ISSUE
D
FIGURE 6
0

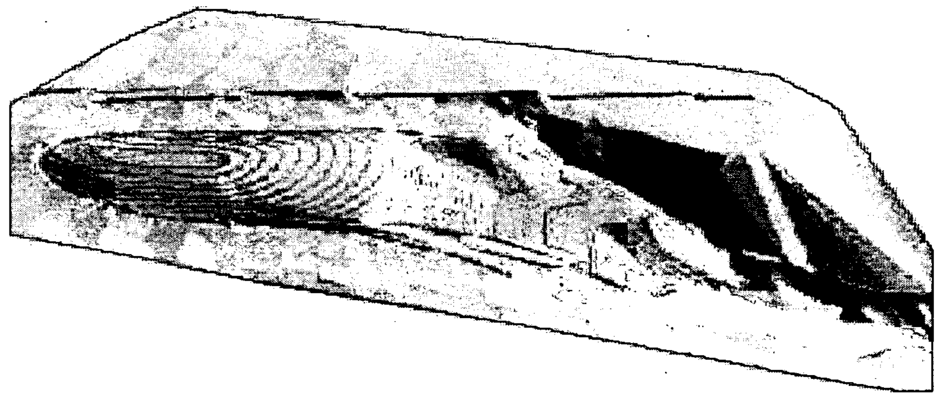
PART	QUAN.	DESCRIPTION	MATERIAL



PRESENT LANDFILL EXISTING GRADE (1) NTS



PRESENT LANDFILL PROPOSED FINAL GRADE (2) NTS



PRESENT LANDFILL PROPOSED FINAL GRADE FOR WASTE RELOCATION OPTION (3) NTS

0 ISSUE	CONCEPTUAL DESIGN DESCRIPTION				PROJECT/WO# NO.
KEYWORDS	TOLERANCES FRACT. ± ANGLE ± DEC. ± UNLESS NOTED OTHERWISE	DESIGN COMPANY: DBS&A			U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO
1.		DESIGNED BY ABRAMS	CMA	12/21/01	Rocky Flats Environmental Technology Site GOLDEN, COLORADO
2.		DRAWN BY BARTLETT	KDB	12/21/01	
3.		CHECKED BY MILLER	MEM	12/21/01	PRESENT LANDFILL EVAPOTRANSPIRATION COVER
4.		APPROVED BY McGOVERN	MFM	12/21/01	3-DIMENSIONAL RENDERINGS
5.	REMOVE BURRS AND SHARP EDGES				
BLDG/FACILITY	NOT ASSIGNED	CLASSIFIER			SIZE: D
ROOM/AREA					DRAWING NUMBER: FIGURE 7
GRID COORD./COL. NO.	SCALE: NTS	LANDLORD			ISSUE: 0

At RFETS, the critical season for cover design is during winter and spring snowmelts. During this period, when plants are dormant, moisture content increases in the cover soil. The cover soil properties and thickness must provide sufficient soil moisture storage to prevent infiltration below the plant root zone. As plants become active, they remove soil moisture in the root zone and gradually dry the cover soil, thus restoring the capacity for continued soil moisture storage.

3.2.2 System Components

The ET cover for the Present Landfill will be constructed of native materials that will provide long-term performance and compatibility with the overall RFETS environmental restoration objectives for site closure. Most materials used in the ET cover consist of soil and rock with relatively common properties. The ET cover design approach allows for a range of properties that will provide suitable performance, with design optimization possible by adjusting layer thicknesses to account for specific properties of selected materials.

Cover profiles for the Present Landfill are shown in Figure 6. The ET cover includes an erosion protection layer on the surface and an underlying soil-rooting medium layer. At the Present Landfill, a gas-venting layer is included below the soil-rooting medium to allow the passive release of methane and provide a well-oxygenated root zone in the venting layer and overlying soil to promote vegetative growth. Material descriptions for each of the ET cover components are provided in the following sections.

3.2.2.1 Soil-Rooting Medium and Erosion Protection Layers

The primary functional component of the ET cover is the soil-rooting medium. An erosion protection soil layer covering the soil-rooting medium will be used to promote the establishment of vegetation and prevent erosion. These combined soil layers will function together as a thick soil-rooting medium, to store soil moisture and allow vegetation to use and remove the moisture, thereby preventing percolation below this layer. The minimum thickness for the combined soil-rooting medium and erosion protection layers is 24 inches, with an average thickness of approximately 56 to 62 inches, based on the cover layout design grades. The soil-rooting medium is designed to be constructed of soils with a significant fraction of fine-grained silt and clay size particles to ensure suitable moisture retention characteristics.

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The purpose of the erosion protection layer is to minimize both wind and water erosion. In the semi-arid areas of the western U.S. wind causes as much erosion as water. This is particularly true at RFETS because of the unusually strong winds it experiences. The native soils at RFETS are typically clayey soils with cobble and gravel surface armoring, which is naturally resistant to wind erosion. Wind and water erosion can be controlled with an ET cover design that incorporates an erosion protection layer similar to natural surface conditions found at the site.

The erosion protection layer will require a soil suitable for a rooting medium with a significant percentage of gravel and cobbles to inhibit erosive forces of wind and water. The erosion protection layer is designed to use local soil with approximately 25 percent coarse fraction by mass. Material testing should be conducted to develop final material specifications depending on properties of available borrow soils. In cross section, these landfill covers will have a 6-inch minimum to 12-inch maximum thickness, gravel-containing erosion protection layer over several feet of soil cover material. Ultimately, this produces a vegetated surface, partially covered with gravel that is resistant to erosion by wind and water.

The ET cover has been designed with gentle slopes, ranging from 3 to 14 percent, to minimize erosion. Geomorphologic observations at RFETS suggest that natural slopes in this range exhibit long-term stability. The cover design slopes are less steep than naturally occurring, well-vegetated slopes observed in the area.

ET covers can be designed to promote the infiltration of storm water at the surface with soil moisture storage provided by the thick soil-rooting layer. Storm water erosion is minimized through the use of coarse-textured surface soils, while fine-grained soils at depth provide moisture storage capacity. Coarse surface soils can enhance performance through (1) increased surface infiltration of precipitation, (2) increased uniformity of infiltration, and (3) reduced runoff. For example, sands have a high permeability on the order of 10 to 30 centimeters per hour (cm/hr), while sandy clay loams have a lower permeability of around 1 cm/hr. A heavy rainfall has an intensity of about 2 cm/hour, a downpour has an intensity of about 5 cm/hr, and a cloudburst has an intensity of 10 cm/hr. Comparing rainfall intensities to soil hydraulic conductivities shows the effects a fine-textured cover has on components of the cover water balance. A cover that allows water to infiltrate at or near the rate of precipitation will greatly reduce runoff and erosion. The infiltration of water also encourages plant growth and evapotranspiration, providing a cycle of positive feedback to prevent long-term erosion.

3.2.2.2 Gas-Venting Layer

A system of piping and vents will be used at the Present Landfill to provide for passive venting of landfill gas. The purpose of the gas-venting system is to provide a well-oxygenated root zone for vegetation on the ET cover. The gas-venting layer will be constructed below the soil-rooting medium and above the existing interim landfill cover and waste materials. In addition to the primary function of the gas-venting layer to maintain a well-oxygenated root zone for vegetation, the gas-venting layer also has a secondary benefit of minimizing subsurface landfill gas migration and impacts. Subsurface landfill gas can cause explosive risks and impact groundwater quality; however, because the gas-venting layer prevents the build-up of gas pressure, the potential for subsurface landfill gas migration and impacts is reduced.

The landfill gas-venting layer for the Present Landfill will use a coarse aggregate material consisting of gravel-sized particles. The gas-venting layer must be substantially free of fine particles in order to possess good gas permeability characteristics. A network of perforated pipe will be installed within a coarse aggregate layer to vent gas to a series of standpipe gas vents. At the conceptual level, the gas-venting layer is designed to be 6 inches thick to provide sufficient thickness for perforated gas-collection piping to be installed within this layer. The final design may alter this thickness to optimize the combined factors related to venting layer thickness, gas permeability, pipe spacing, vent locations, and landfill gas generation rates. Additional vent and piping design details are provided in section 3.2.4.4.

The gas-venting layer will be the only component of the ET cover design that uses synthetic materials, including piping and geotextiles. Although these synthetic materials have a limited design life, they can be used for the gas-venting layer, because generation of methane from solid waste decomposition occurs over a limited timeframe until the degradable waste materials are fully decomposed. Long-term degradation of the synthetic materials, after the methane-producing period ends, will not compromise the continued performance of the ET cover.

The conceptual design has not examined the quality of landfill gas emissions vented from Present Landfill and whether these emissions comply with emission limits and regulatory permitting or reporting requirements. Landfill gas generation rates have been calculated for the Present Landfill conceptual design, and these calculations show that landfill gas generation rates are expected to continue to decline over time, as waste in the landfill decomposes (Appendix E). A more comprehensive analysis of landfill gas emissions and regulatory compliance will be needed as part of the final design.

3.2.2.3 Vegetation

Selected seed mix will be used to establish vegetation on the ET soil covers at the Present Landfill. Revegetation of the ET cover with native species provides compatibility with the surrounding environment and promotes cover longevity. Considerable information on vegetation has already been assembled by the KH Ecology Group, who will provide final specifications for the seed mix based on the seed available commercially at the time of cover completion. Adjustments may be made to the specified seed mix depending on the construction schedule and the season when seeding occurs.

Soil amendments may be needed to promote the initial establishment of vegetation on the ET cover. The need to add soil amendments will depend on nutrient testing of the selected borrow soil. Additional details on the vegetation plan and possible soil amendments are provided in Section 4.

3.2.2.4 Optional ET Apron

As an option to address containment and treatment of the seep at the eastern toe of the Present Landfill, an extension of the ET cover, or an "ET apron," may be added to the design. The ET apron location and conceptual design configuration is shown in Figure 4. The ET apron will use increased ET to dry up and eliminate water currently discharged at the seep. Elimination of the seep using this approach may be an effective and low-cost solution to achieve compliance with RFCA Attachment 10, which specifies surface water quality requirements. If the seep can be eliminated, compliance is achieved. Water balance modeling needs to be completed during the final design to demonstrate the effectiveness of the ET apron concept.

3.2.2.4.1 Seep Treatment and Control

The ET apron is an attractive approach for control because the system will operate passively. A passive treatment approach will have long-term advantages over other active treatment systems, which might be considered. Whereas many conventional treatment options require long-term operation, maintenance, and monitoring, the ET apron can eliminate these operational issues.

The conceptual design provides an option to construct the ET apron on approximately 6 acres at the eastern end of the Present Landfill. This extension of the Present Landfill ET cover will be recontoured to create a relatively flat (approximately 1 percent slope) treatment area immediately east of the current seep location. The ET apron will be seeded to establish vegetation to increase ET and eliminate the existing seep.

The ET apron will include flow control structures to distribute water flow in the area of the existing landfill seep. The conceptual design envisions a subsurface flow distribution system consisting of French drain type rock and gravel filled trenches to provide pathways for passive flow in the shallow groundwater system. Pipe will not be used in the gravel drains because it has a limited design life. The trenches will provide high transmissivity pathways to distribute water across the surrounding area. Final design of the subsurface flow distribution system in terms of length, depth, and spacing of drains will require considerable site investigation, as described in the geotechnical investigation in Section 6, below. The final design should be coordinated with other RFETS efforts to control groundwater at the Present Landfill.

The size of the ET apron for the conceptual design is based on the acreage needed for vegetation to utilize and remove all of the 2 to 3 gpm flow from the existing seep. This flow rate is equivalent to an annual flow of about 3 acre-feet per year. This seepage flow rate, distributed by subsurface flow across the 6-acre ET apron, provides only about 0.5 acre-foot of water per acre each year. Vegetation can typically utilize approximately 3 acre-feet of water per acre, or more, each year. Therefore, the ET apron is designed to provide enough increased evapotranspiration to eliminate the seep.

The ET apron will be planted with plant species recommended by the KH Ecology Group. Suitable plant species will differ from vegetation on the main ET cover, since the ET apron will be designed with the seep level and water table in the shallow subsurface. Suitable plant species may include phreatophytes, which establish root systems in the shallow water-bearing zone. The vegetation can be selected by the KH Ecology Group as most appropriate to contribute to site-wide RFETS restoration objectives.

3.2.2.4.2 Soil Borrow Source

Excavation and regrading of soil to construct the 6-acre ET apron may also provide a suitable soil borrow source to supply material for construction of the ET cover over the Present Landfill. A total of approximately 200,000 cy of material will be excavated under the conceptual design grading plan. If used as a borrow source, the ET apron excavation can provide all of the soil needed for construction of the ET cover.

The on-site soil characteristics are suitable to provide material for various components of the ET cover. As needed, soil screening and processing operations may be set up on-site to generate specified soil, gravel, and rock gradations from the on-site material. In this way, additional rock may be added to the erosion protection layer, or clean gravel, free of fines, may be generated for the landfill gas-venting layer. Removal of gravel and rock will also serve to improve the water-holding capacity of the soil-rooting medium, which accounts for the largest quantity of material required.

In addition, the use of on-site soil from the ET apron excavation will be cost-effective. A 1994 borrow source evaluation considered advantages and disadvantages of on-site and off-site borrow sources in detail (EG&G, 1994), and showed that on-site sources would be much less expensive than off-site sources. Transportation costs to import off-site soil were calculated to be more than twice the total cost of on-site soil. A similar cost differential is shown in the construction cost estimate provided in Section 9.

3.2.3 Storm Water Control

The conceptual design approach to storm water control centers on the need to provide for 1,000-year longevity without excessive erosion. To meet the design criterion for longevity, storm water control is achieved by dispersed, overland flow without the use of storm water channels that focus erosive forces. The design will allow storm water to flow off of the ET cover on gentle grades ranging from 3 to 14 percent. This storm water will shed to surrounding native landscape where the water will not come in contact with landfill waste.

The conceptual cover grading plan has been designed to shed storm water in a relatively uniform fashion around the entire cover (Figure 4). Over most of the cover, this is achieved through use of existing grades. At the east end of the landfill, however, waste has been placed on the hill crest to the northwest and southwest of the East Landfill Pond. Rather than focus storm water into a channelized area where erosion control would be difficult to achieve, the conceptual design provides for a wedge of soil to be placed above the East Landfill Pond, filling the valley to a gentle 14 percent grade. This slope is crowned outward to disperse the overland flow.

The conceptual design relies on dispersed overland flow rather than storm water channeling because channels require more long-term maintenance and operation activities.

The ET cover design can support an overland flow approach, because the ET cover will promote infiltration into (but not through) the cover soil and minimize runoff. Infiltration is promoted through the use of highly permeable topsoil and vegetation that reduces downslope flow. The final topsoil design specification should have a permeability on the order of 3 inches per hour (in/hr) (8 cm/hr), to allow infiltration of heavy rainfall.

Overall, the ET cover design will provide runoff characteristics that are similar to undisturbed, native areas at RFETS. Construction of new storm water detention ponds should not be needed to address increased runoff resulting from cover construction. Runoff from the Present Landfill will be addressed within the overall RFETS storm water management system.

3.2.4 *Landfill Gas Control*

Control of landfill gas is an important design consideration for the ET cover, since the cover's performance depends on well-established vegetation. Methane generated by waste decomposition can affect vegetative growth on landfill covers, by starving plant roots of needed oxygen. Unrestricted root growth throughout the full thickness of the cover is critical to the proper performance of the ET cover. The conceptual ET cover design includes a passive, landfill gas-venting system installed below the soil-rooting medium, to maintain a well-oxygenated root zone to support vegetation. The conceptual design included an evaluation of landfill gas generation rates, which is presented in detail in Appendix E.

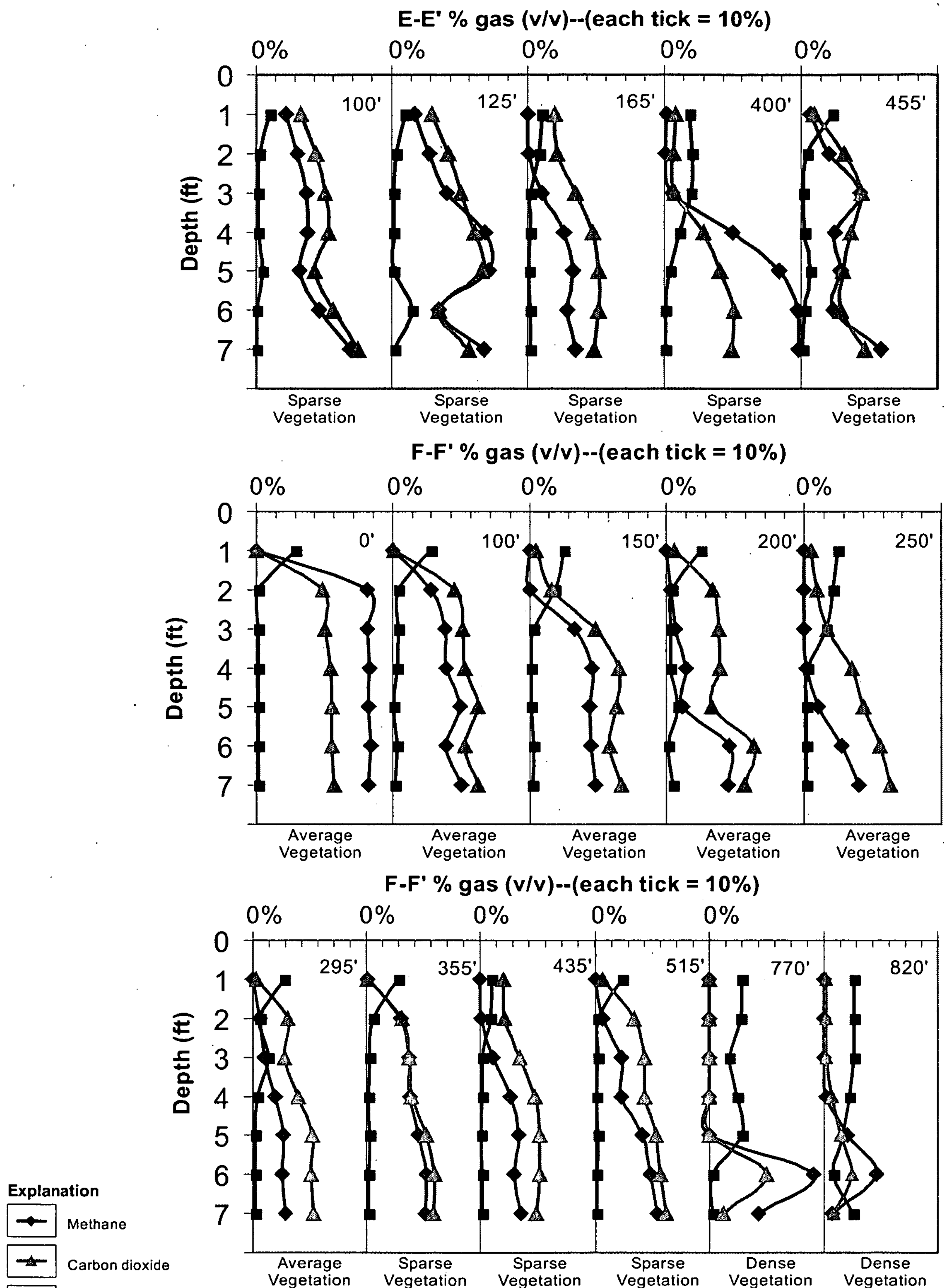
3.2.4.1 Gas Probe Investigation

During September 2001, KH conducted a field investigation to examine landfill gas conditions in the existing, interim, soil cover over the Present Landfill. The investigation used a soil probe to collect gas samples from the interim cover soils and underlying solid waste. The probe was used to collect samples at 1-foot intervals, up to 7 feet below the cover surface. Probing was conducted on transects across the landfill cover, giving a representative distribution of gas measurement.

Results of the gas probe investigation are depicted graphically in Figure 8. The results show that oxygen is depleted and methane is elevated at depths of only 1 to 2 feet below the cover surface. The investigation indicates that gas generation rates in the Present Landfill are causing significantly elevated methane concentrations in the interim cover soils, at levels, which will significantly limit plant root growth. The gas probe investigation provides current information to support design decisions on the necessity of the gas-venting layer.

3.2.4.2 Gas Generation Modeling

Landfill gas is generated within a waste disposal site by the natural decomposition of the organic materials present. Methane (CH_4) and carbon dioxide (CO_2) are the primary constituents of landfill gas, and are produced by microorganisms within the landfill under anaerobic conditions. The Present Landfill contains decomposable waste materials including mainly municipal and industrial solid waste, and some sludges and hazardous waste. The total



ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Soil Gas Profiles

Figure 8

S:\Project\9373\Drawings\Figures_4-15-02\Landfill\Figure_8ff.cdr volume of solid waste in the Present Landfill is reported to be approximately 403,600 cy (308,600 cubic meters [m^3]) (ERM, 1994). Along with the methane produced by waste decomposition, landfill gas typically contains trace concentrations of non-methane organic compounds (NMOCs). This NMOC fraction often contains various hazardous air pollutants (HAPs) and volatile organic compounds (VOCs) (EPA, 1998).

Conditions of the waste and landfill are also of vital importance to the generation of landfill gas. Moisture content of the waste is by far the most critical variable in the determination of landfill gas generation rate, controlling the rate of waste decomposition and gas production. Moisture content does not change the total amount of gas that is produced from a given waste quantity, but it determines the rate and duration of gas generation. A methane survey conducted at the Present Landfill found that waste is moist (ERM, 1994), and high moisture conditions are expected to persist due to seepage into the lower portion of the landfill. Therefore, waste decomposition and gas generation is likely to occur in the Present Landfill at near peak rates.

Landfill gas generation rates for the Present Landfill were estimated using EPA's Landfill Gas Emissions Model Version 2.0 (LandGEM). The model shows a peak landfill gas (LFG) generation in 1998, immediately after the closure of the landfill, and LFG generation rates are now declining. The maximum gas generation rates for 1998 were:

- Methane = 31.1 cubic feet per minute (cfm)
- Carbon dioxide = 25.4 cfm
- NMOCs = 0.14 cfm
- Total LFG = 56.7 cfm

Figure 9 is a graphical representation of the LandGEM model output. The modeling results indicate that landfill gas generation is expected to reach very low rates in a timeframe of approximately 25 years. The current methane generation rate of approximately 50 cubic feet per minute (cfm) is expected to decline to less than 20 cfm by 2025, and to less than 3 cfm by 2075. The majority of methane produced by waste decomposition (approximately 80 percent) is calculated to occur by 2025, and nearly all of the gas production is expected to occur by 2075.

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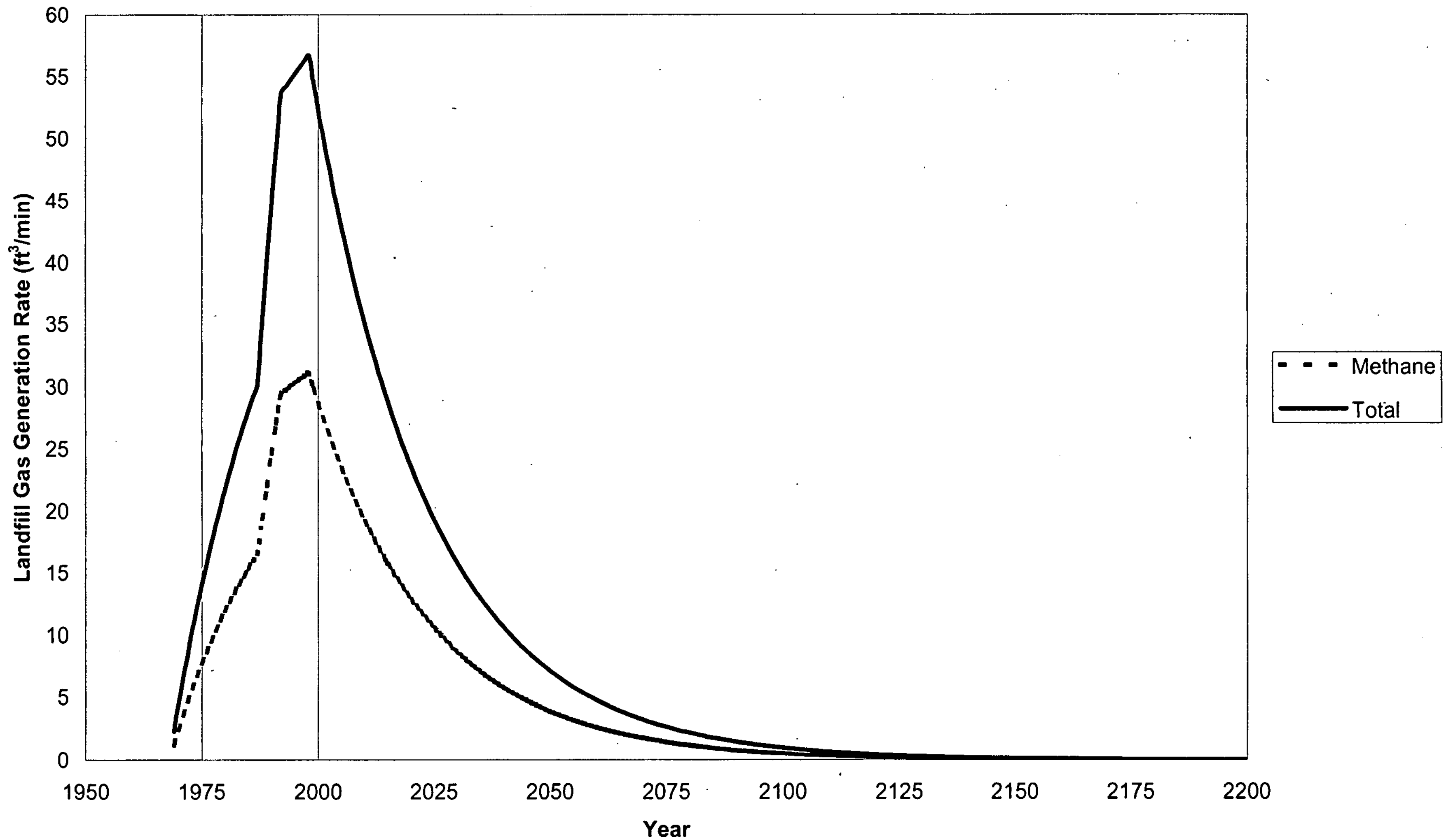


Note: Methane generation rate constant, k=0.04

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Landfill Gas Generation at the Present Landfill

Figure 9

3.2.4.3 Vent and Piping Design

The gas-venting layer design is shown schematically in Figure 10. It includes:

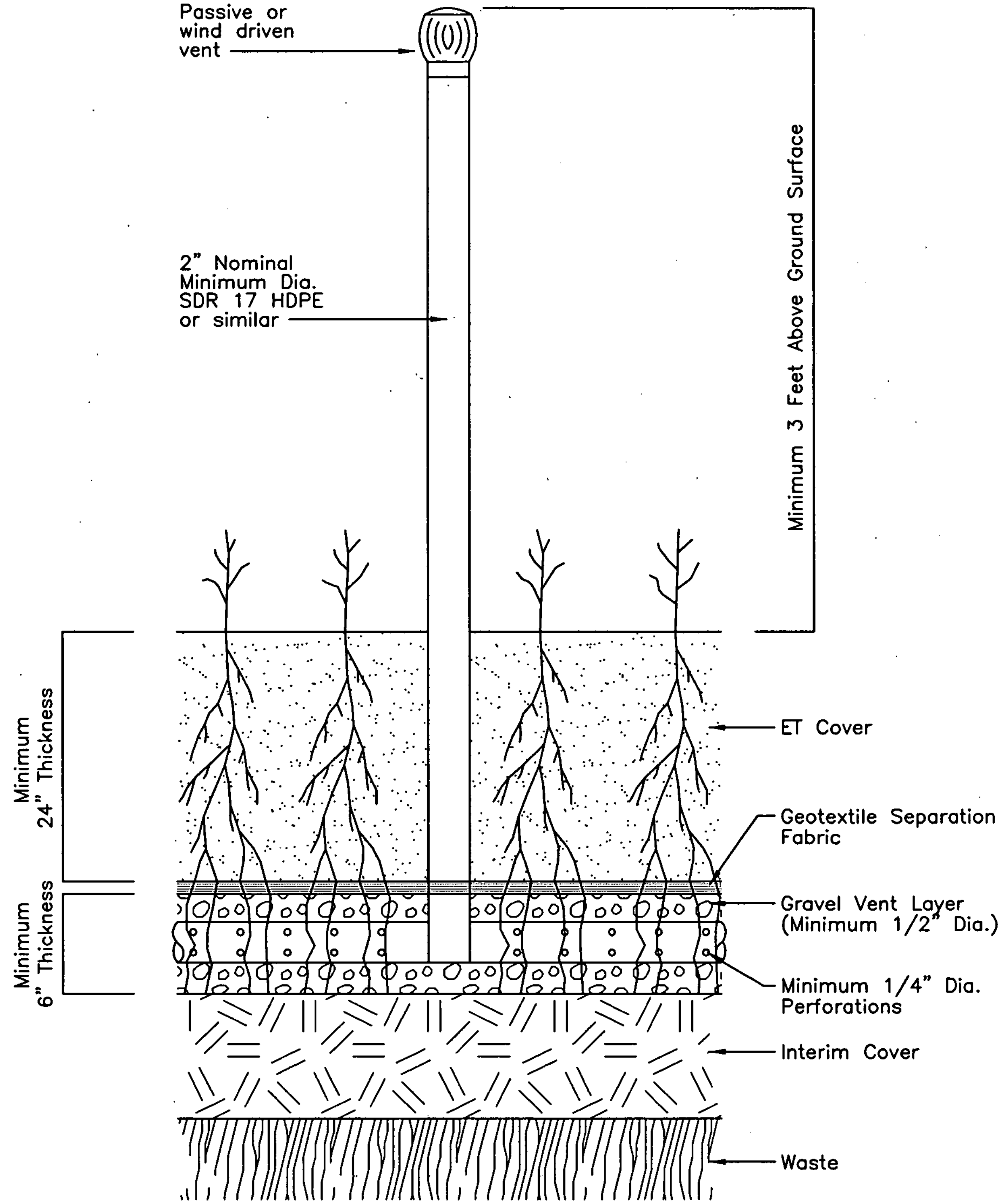
- A network of perforated vent pipes laid horizontally to collect landfill gas.
- A series of vertical vent pipes to allow passive venting of landfill gas to the atmosphere.
- A geotextile filter fabric placed above the gas-venting layer to prevent fine-grained particles from filtering down from the overlying soil-rooting medium into the aggregate.

The piping network will consist of a series of perforated pipes in a grid pattern to provide redundancy and an added factor of safety in design. Vent pipe design must be compatible with final land use plans, particularly if public access to the area is allowed. The network of piping and vents will provide secondary gas pathways should an individual pipe segment become blocked or otherwise fail. A grid of perforated piping at approximate 100-foot spacings should provide adequate gas capture and flow rates to provide a well-oxygenated soil-rooting zone for the ET cover. Final design of the gas-venting system will need to determine the required pipe spacing in conjunction with coarse aggregate gas permeability specifications. The system can also be used with blowers if needed to meet facility performance requirements.

Periodic maintenance of the gas vents will be needed during the operational life of the gas-venting system. When gas generation rates have declined to a level at which the venting system is no longer needed, after approximately 25 to 75 years, the gas vents may be removed. The vent standpipes can be cut off and plugged below grade, with the remainder of the piping network left in place. The holes left by plugging will be replaced with soil of a lower permeability than the rest of the ET cover soil, thereby eliminating any possible preferential pathway for either gas flow or moisture infiltration. The points of cover repair will revegetate naturally and effectively merge with the ET cover vegetation.

3.2.4.4 Landfill Gas Regulatory Overview

The installation of an ET cover will not change the regulatory compliance status of the Present Landfill. At this time the landfill does not appear to have any applicable regulatory requirements on air emissions. The ET cover is not expected to increase emissions of any contaminant;



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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Conceptual Passive Vent Well and Vent Layer Detail

Figure 10

therefore, the cover will not trigger any emissions based regulatory program. Cover construction permits may be required that pertain to particulate emissions.

The application of air quality regulations to the Present Landfill should be addressed as part of the overall air quality analysis of the RFETS site. The ET cover construction is not expected to increase emissions from the landfill or affect any related regulatory requirements that may already apply to the landfill.

3.2.5 Slope Stability

Slope stability of the proposed ET cover for the Present Landfill was analyzed to ensure that the cover will be stable and remain in place permanently, under both static and dynamic (seismic) conditions. The analysis of slope stability demonstrates compliance with the design criteria presented in Section 2, which requires compliance with the following factors of safety.

- Final slopes will not exceed 14 percent to promote stability. The minimum FOS for slopes under static conditions will be 1.5.

- Demonstrate that the final cover can withstand the maximum horizontal acceleration in earthen materials for the landfill. The minimum factor of safety for slopes under dynamic (seismic) conditions will be 1.3.

The slope stability analysis demonstrates that the ET cover will meet the required factors of safety and the specified slope angles. The maximum design slope for the Present Landfill is 14 percent, which occurs on the east side of the landfill. The ET cover is designed with relatively gentle slopes not only for slope stability both also for erosion resistance.

The design slopes for the ET cover conceptual design are based on the work of other investigators at RFETS, who have analyzed slope stability for similar applications. Slope stability of a final cover for the Original Landfill (OU5) was evaluated in a previous report (DOE, 1995). The Original Landfill exhibits unstable slope conditions in an area of shallow groundwater and seeps, south of the RFETS industrial area. The Original Landfill contains solid waste deposited on Rocky Flats Alluvium, which overlies weathered claystone. These geotechnical conditions are similar to the Present Landfill. This 1995 study found that slopes of 14 percent (7:1) are stable for the final cover profile over the saturated geologic materials. Additional, unpublished slope stability analyses for RFETS have shown similar results, with 14 percent slopes (7:1) stable over saturated materials and 18 percent slopes (5.5:1) stable over unsaturated materials (Doty, 2001).

A description of the slope stability analysis and results is provided in the following section.

3.2.5.1 Modeling Approach

Slope stability modeling was performed by using the computer-based program XSTABL, Version 5. XSTABL was developed by Sharma (1995) for the purposes of creating a fully integrated slope analysis program in which the user can develop the slope geometry and perform the analysis all in one single program. The slope analysis portion of XSTABL uses a modified version of the popular STABL program, originally developed by Purdue University. XSTABL was chosen to perform the slope stability analysis for RFETS due to its simplicity of use, accuracy, and overall reputation as an excellent tool for performing slope stability analyses for these types of projects.

The first step in modeling the slope stability was to enter a simplified geometry of the steepest slope at the Present Landfill into XSTABL. An assumption is made that if the steepest slope meets the specified factors of safety, then all other slopes will meet the requirements as well. As described above the steepest slope at the landfill site is the east slope at a design grade of 14 percent. The geometry was entered into the model by plugging coordinate data from the cross-sections into the model.

The next slope stability modeling step was to assign soil properties to each of the soil units (layers) that comprise the cover. Model input parameters were conservative with regard to predicting possible slope failure mechanisms. The soil properties required by XSTABL are wet bulk density, angle of internal friction, and cohesion. Since test data were not available for all of these parameters, conservative assumptions and typical values were used to perform the analysis. Table 3 summarizes soil properties for the ET cover and the Present Landfill as used in the model.

Table 3. Slope Stability Material Properties for ET Cover and Present Landfill

Soil Layer	Soil Unit No. (as assigned in the model)	Wet Bulk Density (pcf)	Angle of Internal Friction (degrees)	Cohesion (psf)
Erosion protection layer	1	118.6	30	0.5
Soil-rooting medium	1	118.6	30	0.5
Landfill gas-venting layer	3	96.3	30	0.0
Intermediate cover	1	118.6	30	0.5
Solid waste	2	33.0	10	0.0
Native soil beneath waste	1	118.6	30	0.5

pcf = Pounds per cubic foot psf = Pounds per square foot

The final step in modeling was to run a circular failure analysis using Bishop's Method of Slices on the slope geometry using the soil properties shown in Table 3. Static analysis was performed initially, then a coefficient of horizontal acceleration was entered into the model for dynamic analysis. The value used for horizontal acceleration was attained from the U.S. Geological Survey (USGS) National Seismic Hazard Mapping Project. A coefficient of 0.112 g or 11.2 percent of gravitational acceleration was used in XSTABL for the RFETS slope analysis. This value corresponds to the Golden, Colorado area and indicates with a 2 percent probability of an earthquake of the above intensity in the next 50-year period. This equates to a 10 percent probability of a 0.112 g earthquake in the next 250 years, or a 40 percent probability within the next 1,000 years. Over the 1,000-year design life of the ET cover, a significant probability exists for a seismic event of this intensity; therefore, the cover design must provide a sufficient factor of safety to demonstrate stability under dynamic conditions. Additional analyses were completed to show slope stability for larger potential earthquakes with a ground acceleration up to 0.25 g. This is the earthquake cited by DOE (1995) as having a scaled return probability of 1,000 to 10,000 years.

3.2.5.2 Modeling Results

The XSTABL analysis results were favorable, showing the ET cover to be stable under all conditions modeled. Results from XSTABL are presented in terms of factor of safety. In theory, any factor of safety of 1.0 or higher means the slope will not fail. But because the process of modeling usually simplifies a situation the factors of safety are set to higher standards than 1.0 to allow for additional tolerance. As stated above, the required factors of safety set for RFETS are 1.5 under static conditions and 1.3 under dynamic conditions. XSTABL generated the ten most critical surfaces for the slope of concern and therefore output the ten lowest factors of safety. Table 4 summarizes slope stability results for the Present Landfill.

Table 4. Slope Stability Analysis Results for the Present Landfill

Area Analyzed	Type of Analysis	Minimum Factor of Safety
East cover slope at 14% grade	Static	4.766
East cover slope at 14% grade	Dynamic	2.458
East cover slope at 14% above existing waste slope at 31% grade	Static	13.793
East cover slope at 14% above existing waste slope at 31% grade	Dynamic	3.220

The Present Landfill was analyzed in two distinct critical areas. The first point of analysis was the steepest slope at the Present Landfill, which is the 14 percent east slope. Under both static and dynamic conditions the factors of safety are well above the specified values of 1.5 (static) and 1.3 (dynamic) for this slope. The second point of analysis was the portion of the east slope of the landfill that overlies the east edge of waste that is at an existing grade of approximately 31 percent. Since this waste is graded at such a steep angle it was a critical area to analyze to ensure the slope containing the waste would remain structurally sound once the cover was constructed over the waste slope. XSTABL results for this area generated factors of safety several times the design criteria. This indicates that the waste, the east slope, and the entire landfill will remain in place even during a probable seismic event.

The slope stability analyses completed for the conceptual design show that the gentle ET cover slopes are conservative with regard to slope stability. At the final design stage, more detailed slope stability analyses will be needed that include testing of on-site geologic materials and materials planned for cover construction. A complete evaluation is needed of geotechnical conditions present, including possible saturated foundation conditions within the formations supporting the cover. These slope stability analyses should be coordinated with studies currently underway at RFETS to evaluate shallow groundwater conditions and control.

3.2.5.3 Waste Settlement

Solid waste in landfills undergoes long-term settlement, which affects the landfill final cover. This settlement causes gradual changes in the cover slopes and can potentially cause damage to landfill covers. The degree of waste settlement expected at the Present Landfill was analyzed to verify suitable design of the ET cover grading plan (Figure 4). Most importantly, settlement must remain within tolerable limits to provide for continued positive drainage, to prevent ponding on the cover, over the full settlement expected for the 1,000-year design life of the ET cover.

Multiple mechanisms control the rate and degree of waste settlement. Sharma and Lewis (1994) summarize the primary settlement mechanisms as follows:

- Mechanical rotation or reorientation of material
- Raveling (repositioning of particles into smaller voids)
- Physical-chemical changes (corrosion and oxidation)
- Biochemical decomposition (decay, fermentation, anaerobic processes, and aerobic processes)

Waste settles under its own mass and additionally under the placement of external loads such as daily soil cover, additional waste, and final cover. Depending on factors such as waste composition, initial compaction, and environmental conditions, waste typically settles from 5 to 30 percent of its original thickness under its own weight (Edil et al., 1990). This primary waste settlement will occur within approximately the first 5 years of placement. Secondary settlement or compression, due to decomposition and creep processes, will decrease with time, but will continue following closure of the landfill. New wastes have not been placed in the Present Landfill for four years; therefore, most primary settlement has already occurred. Most remaining settlement at the Present Landfill will be caused by settlement due to long-term waste decomposition.

The degree of long-term waste settlement was estimated by four of the most widely accepted methods: the Sowers Method, the modified Sowers Method, the Gibson and Lo Model, and the Power Creep Law. These methods were used to evaluate waste settlement for 5, 10, 30, 50 and 1,000-year periods. The final step of the settlement analysis was to apply the elevation changes estimated by the models to the cross-section of the landfill surface and evaluate the resulting change in grade.

Settlement calculation results are summarized in Table 5. The four models provide relatively consistent results, and over each time-step, the models predict additional settlement of approximately 3 percent, yielding an almost consistent 3 percent increase in settlement during the lifetime of the landfill. During early analysis time-steps, the Sowers and Modified Sowers Methods estimate the largest settlement values. Ultimately, the Gibson and Lo Model predicts the greatest degree of settlement, which is shown in the 1,000-year settlement values for this method.

The change in elevation resulting from waste settlement calculated by each method for the 1,000-year analysis was applied to the design surface of the ET cover. Over the cover cross-sections (as shown in Figure 5) the change in cover elevation was analyzed by lowering the surface elevation at each data point analyzed. This resulted in a modified cover surface geometry that reflects the expected final grade after 1,000 years of waste settlement. Total waste settlement amounts to as much as 6 feet in the areas with the greatest waste thickness. The changes in final grade were found to be within tolerable limits, to continue to provide positive drainage from the ET cover. The minimum 3 to 5 percent slopes designed for the top-deck of the landfill cover will provide positive drainage for the 1,000-year design life of the ET cover.

Table 5. Settlement Calculation Summary

Present Landfill Point Location	Sowers Method		Modified Sowers Method		Powers Creep Law		Gibson and Lo Model	
	30 yr	1,000 yr	30 yr	1,000 yr	30 yr	1,000 yr	30 yr	1,000 yr
East-West Cross-Section Settlement (feet)								
A-200	0.29	0.59	0.19	0.39	0.03	0.10	0.12	0.80
A-400	0.60	1.23	0.40	0.81	0.15	0.53	0.31	2.83
A-600	1.09	2.22	0.72	1.47	0.10	0.36	0.47	3.01
A-800	1.23	2.50	0.81	1.65	0.11	0.41	0.53	3.37
A-1000	1.32	2.68	0.87	1.77	0.12	0.44	0.57	3.62
A-1200	1.14	2.31	0.75	1.53	0.34	1.26	0.54	5.63
A-1400	1.07	2.18	0.71	1.44	0.29	1.07	0.53	5.19
A-1600	0.69	1.41	0.46	0.93	0.46	1.69	0.16	2.81
A-1800	0.22	0.45	0.15	0.30	0.30	1.11	0.01	0.30
North-South Cross-Section Settlement (feet)								
B-100	0.63	1.27	0.41	0.84	0.06	0.21	0.27	1.72
B-300	0.83	1.68	0.55	1.11	0.08	0.27	0.36	2.27
B-400	0.94	1.91	0.62	1.26	0.09	0.31	0.40	2.58
B-500	0.92	1.86	0.61	1.23	0.08	0.30	0.39	2.52
B-700	0.85	1.72	0.56	1.14	0.08	0.28	0.37	2.33

Along with providing positive drainage, the ET cover is also resistant to possible damage caused by differential settlement. Differential settlement can cause shearing in covers with traditional design using compacted clay and/or synthetic liner materials. Because the ET cover is constructed of non-cohesive soil, the Present Landfill cover is resistant to possible damage. The soil cover can undergo slow deformation, without being subject to cracking or other damage. This characteristic of ET covers allows these soil covers to outlast traditional landfill cover designs.

3.2.6 Site Preparation

Prior to construction of the ET cover, site preparation work to remove existing infrastructure will be needed. At the Present Landfill, site preparation will need to address:

- Existing gas vents
- East Landfill Pond and dam
- Existing surface water and groundwater control structures
- Clearing and grubbing

Each of these site preparation items is discussed in detail in the following sections.

3.2.6.1 Existing Gas Vents

A series of gas vents were installed in the interim landfill cover in 1997. The existing vents consist of vertical standpipes installed through the cover and into the underlying waste to allow passive venting of landfill gas. These existing vents will need to be removed prior to construction of the ET cover. Removal of the vents can be easily completed, either by pulling the casing or by plugging the casing with bentonite or grout. If the casing is left in place, it should be cut off below ground surface. The existing gas vents will not be needed following installation of the ET cover gas-venting system.

3.2.6.2 East Landfill Pond and Dam

The East Landfill Pond and dam will need to be removed, prior to cover construction, due to the proximity of the pond to the steep, eastern slope of the Present Landfill. The pond is located approximately 100 feet from the eastern toe of the slope, and a wetlands begins adjacent to the toe of the landfill slope and extends to the dam crest, approximately 600 feet to the east. The seep emerges from the landfill within the wetlands. In order to meet design requirements limiting the final cover slope, the landfill cover must extend beyond the existing landfill slope and will infringe on the pond and wetlands.

The East Landfill Pond was constructed in 1974 as a catchment to prevent discharge of the seep to surface water in No Name Gulch. Although eliminating the pond will reduce wetland habitat, it appears that maintaining the pond is not compatible with overall closure requirements for the Present Landfill. Two fundamental issues are apparent:

- *Flow Reduction*: The existing seep, which flows to the pond, will have a reduced flow as a result of the ET cover reducing infiltration into the landfill and additional groundwater controls being investigated at RFETS to reduce groundwater inflow to the landfill. The reduced seep flow will affect the pond level. An overall water balance for the pond, considering inflows from the seep, groundwater, and surface water, has not been determined.

- *Sedimentation*: Long-term sedimentation will gradually lead to infilling of the shallow, East Landfill Pond. Any additional surface water discharge routed into the pond to make up for the reduced seep inflow, will bring an associated sediment load. Preservation of the pond appears incompatible with the 1,000-year longevity for landfill closure.

Removal of the East Landfill Pond and dam will require that the water in the pond be appropriately discharged.

The conceptual design grading plan calls for removal of the upper portion of the dam and infilling of the pond to construct the ET apron. This earthwork will be completed during cover construction, at the same time a thick wedge of soil is placed over the existing east slope of the landfill. The ET apron, located over the same area as the current pond and dam, will provide similar wetland type habitat as an offset for removal of the pond and surrounding wetland.

3.2.6.3 Existing Surface Water and Groundwater Control Structures

Existing surface water and groundwater control structures route water around the Present Landfill, and discharge the water at multiple points east of the landfill. The effectiveness of these control structures is being examined by others, and the results of this evaluation will determine whether the structures need to be maintained and if additional engineering controls are needed to reduce seepage inflows to the landfill.

The ET cover will overlie portions of the groundwater control structures at the eastern end of the landfill. Final design of the ET cover must be coordinated with the evaluation and design of groundwater control systems to provide compatibility between the two efforts.

The existing surface water diversion ditch around the landfill perimeter should be filled and eliminated during the ET cover earthwork. As described in Section 3.2.3, surface water runoff

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from the ET cover will be minimized through vegetation and permeable surface soil, and the minor runoff will be discharged by dispersed overland flow. Eliminating the surface water ditch will also reduce infiltration at the landfill perimeter, which may contribute to groundwater inflow into the landfill waste. Filling the ditch will be a minor additional earthwork activity during cover construction.

3.2.6.4 Clearing and Grubbing

All areas where the cover will be placed and areas of excavation for soil borrow will be cleared and grubbed prior to starting earthwork. Existing vegetation should be stripped to provide consistent adhesion between the existing soils and the overlying soil materials placed for cover construction. This is particularly important on the eastern slope of the Present Landfill, where steep slopes of approximately 30 percent currently exist. Clearing and grubbing this slope will avoid creating a potential slippage plane along a layer of matted vegetation. Likewise, vegetation should be stripped from the surface of soil borrow areas to provide consistent borrow soil and avoid irregular amounts of plant material mixed with the borrow soil.

A suitable means of disposal will need to be determined for the vegetation and soil generated by clearing and grubbing. The possibility of contaminants in the material may need to be considered and could affect disposal alternatives. At the Present Landfill, where organic solid wastes have been disposed, it appears suitable to place and compact the clearing and grubbing spoils on a portion of the landfill where additional fill may be useful to reach final design grades. The spoils will exhibit properties much like the rest of the solid waste mass in the landfill and will not affect the ET cover.

3.2.7 Asbestos Disposal Areas

Two asbestos disposal areas are located at the eastern end of the Present Landfill, on slopes above the East Landfill Pond (Figure 4). The location of the asbestos disposal areas presents design challenges regarding the configuration of final cover grades, while meeting slope grading limitations for slope stability and erosion resistance. To maintain the maximum slope of 14 percent, a thick wedge of soil fill must be placed on the east landfill slope, filling the valley between the north and south asbestos disposal areas.

A second option for consideration is relocating the asbestos into the main landfill disposal cell. Relocating the asbestos allows for significant reduction of the eastern extent of the ET cover and using a much smaller quantity of soil required for cover construction. Asbestos is typically handled in this type of operation by thoroughly wetting the material prior to excavation using a front-end loader, and placement into a haul truck with a plastic liner to cover and seal-in the material. The asbestos can then be disposed of in narrow trenches and immediately covered with soil. Relocating the asbestos disposal cells will require careful handling of the material and compliance with all air quality requirements and worker safety requirements.

3.2.7.1 Design Options

The Present Landfill ET cover conceptual design configuration includes two different design options:

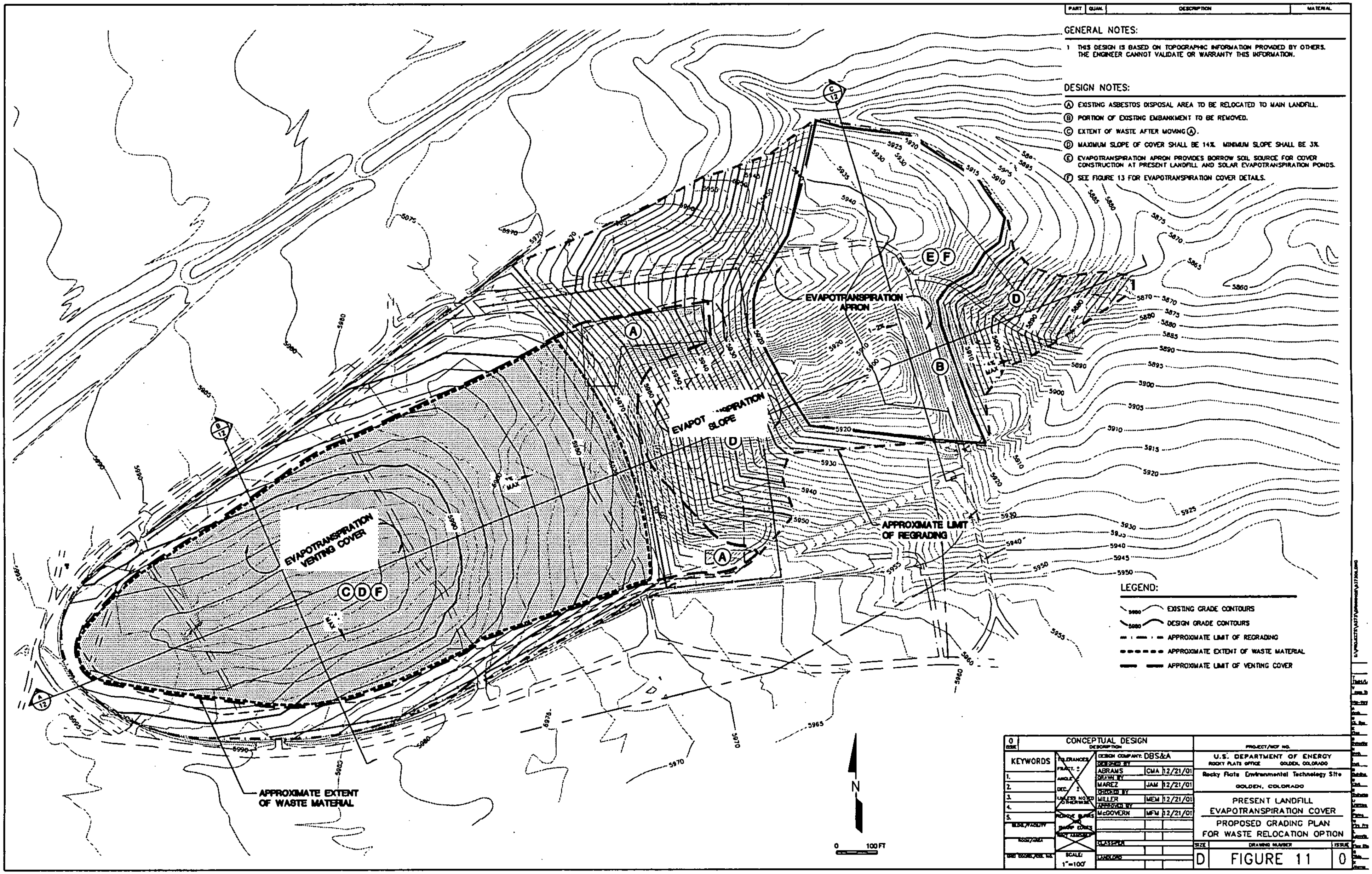
- *Primary Option*: Cover asbestos in-place. The conceptual ET cover configuration for this option is shown in Figure 4.

- *Secondary Option*: Relocate asbestos into main disposal cell. The conceptual ET cover configuration for this option is shown in Figure 11. Cover cross-sections and details for the waste relocation option are shown in Figures 12 and 13.

Selecting between the two conceptual design options is not straightforward at this point. This is in part due to an absence of information regarding the nature and quantity of asbestos disposed and the exact location and depths of asbestos disposal cells. Some of the advantages and disadvantages of the two options are described in the following sections.

3.2.7.2 Cover Asbestos In Place

Leaving the asbestos in its current disposal locations and covering it in place has the primary advantage of minimizing potential risks of exposing and potentially releasing contaminants. Administrative efforts to conduct the asbestos relocation are avoided and the overall project schedule to complete final closure may be expedited. Also, regulatory approvals to complete the asbestos relocation are avoided and public concern will not be raised as a result of waste excavation.


GENERAL NOTES:
1. THIS DESIGN IS BASED ON TOPOGRAPHIC INFORMATION PROVIDED BY OTHERS. THE ENGINEER CANNOT VALIDATE OR WARRANTY THIS INFORMATION.
DESIGN NOTES:
(A) EXISTING ASBESTOS DISPOSAL AREA TO BE RELOCATED TO MAIN LANDFILL.
(B) PORTION OF EXISTING EMBANKMENT TO BE REMOVED.
(C) EXTENT OF WASTE AFTER MOVING (A).
(D) MAXIMUM SLOPE OF COVER SHALL BE 14%. MINIMUM SLOPE SHALL BE 3%.
(E) EVAPOTRANSPIRATION APRON PROVIDES BORROW SOIL SOURCE FOR COVER CONSTRUCTION AT PRESENT LANDFILL AND SOLAR EVAPOTRANSPIRATION PONDS.
(F) SEE FIGURE 13 FOR EVAPOTRANSPIRATION COVER DETAILS.
LEGEND:
EXISTING GRADE CONTOURS
DESIGN GRADE CONTOURS
APPROXIMATE LIMIT OF REGRADING
APPROXIMATE EXTENT OF WASTE MATERIAL
APPROXIMATE LIMIT OF VENTING COVER
EVAPOTRANSPIRATION APRON
EVAPOT ANSPIRATION SLOPE
EVAPOTRANSPIRATION VENTING COVER
APPROXIMATE LIMIT OF REGRADING
APPROXIMATE EXTENT OF WASTE MATERIAL
N
0 100 FT
CONCEPTUAL DESIGN
KEYWORDS
DESIGN COMPANY: DBS&A
ABRAMS CMA 12/21/01
MAREZ JAM 12/21/01
MILLER MEM 12/21/01
McGOVERN MFM 12/21/01
SCALE: 1"=100'
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
PROPOSED GRADING PLAN
FOR WASTE RELOCATION OPTION
D FIGURE 11 0

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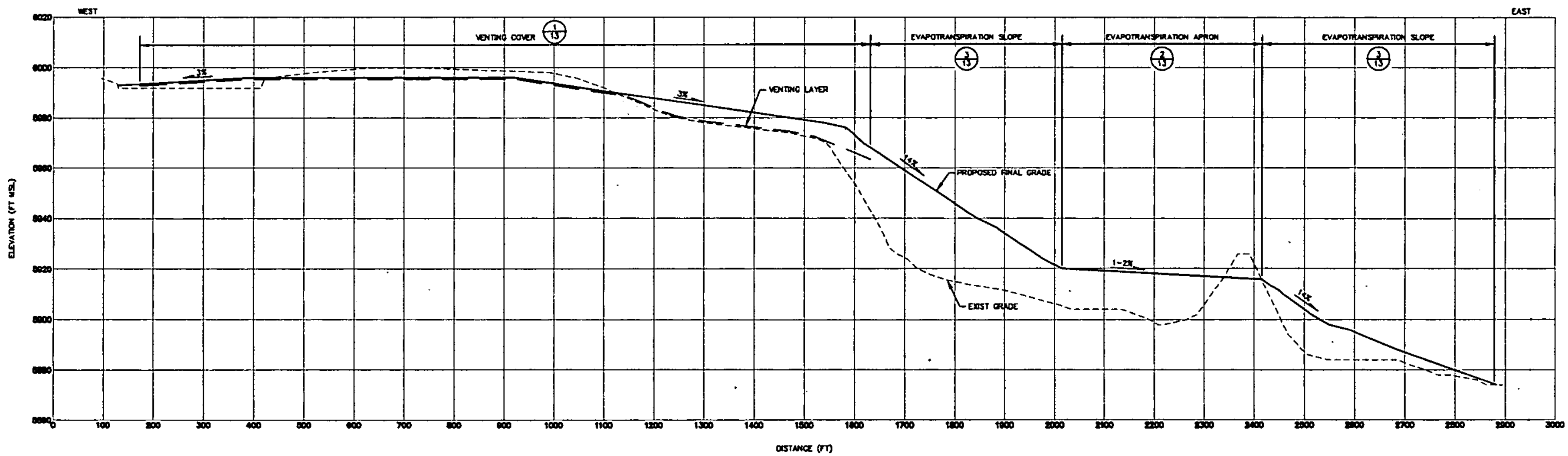

PRESENT LANDFILL SECTION VENTING COVER AND EVAPOTRANSPIRATION APRON (A / 11)

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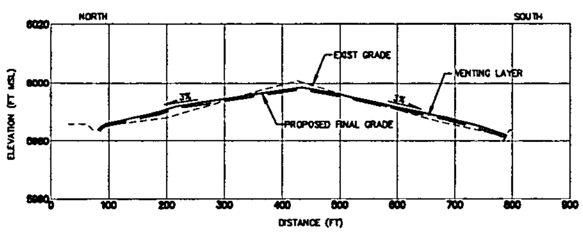
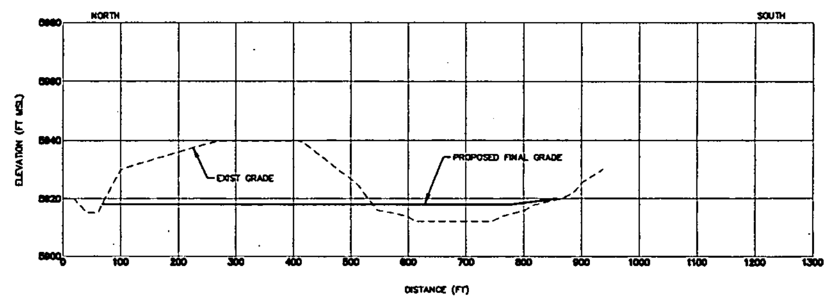
VERT: 1"=20'



PRESENT LANDFILL SECTION VENTING COVER (B / 11)

HOR: 1"=100'
VERT: 1"=20'



PRESENT LANDFILL SECTION EVAPOTRANSPIRATION APRON (C / 11)

HOR: 1"=100'
VERT: 1"=20'

0	CONCEPTUAL DESIGN		
KEYWORDS	DESIGN COMPANY: DBS&A		
	DESIGNED BY: ABRAMS	CMA	12/21/01
	DRAWN BY: MAREZ	JAM	12/21/01
	CHECKED BY: MILLER	MEM	12/21/01
	APPROVED BY: McGOVERN	MFM	12/21/01
	SCALE: AS NOTED		

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
TYPICAL CROSS SECTIONS
FOR WASTE RELOCATION OPTION

SIZE: D | DRAWING NUMBER: FIGURE 12 | ISSUE: 0

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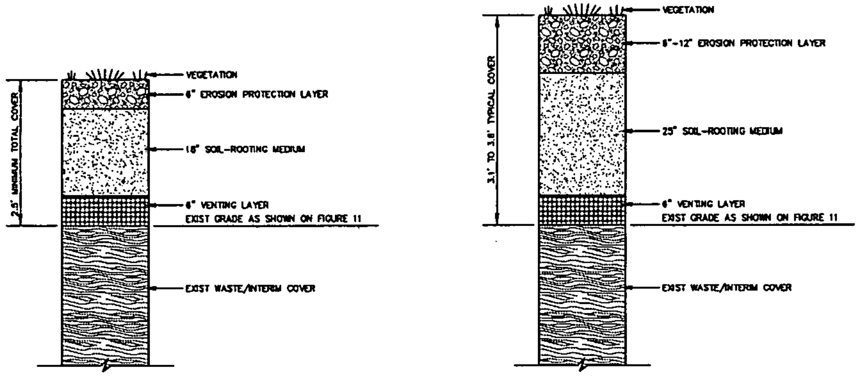
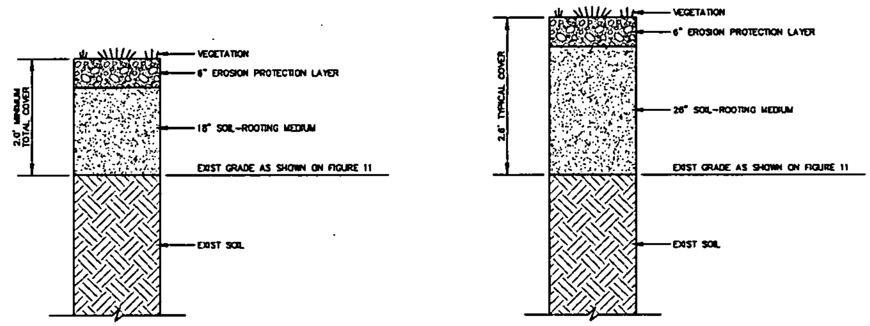


MINIMUM DESIGN THICKNESS

AVERAGE THICKNESS BASED ON DESIGN GRADES

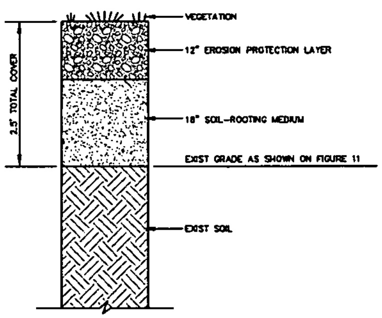
PRESENT LANDFILL VENTING COVER (1/12)
NTS



MINIMUM DESIGN THICKNESS

AVERAGE THICKNESS BASED ON DESIGN GRADES

EVAPOTRANSPIRATION APRON (2/12)
NTS



MINIMUM DESIGN THICKNESS

PRESENT LANDFILL EVAPOTRANSPIRATION SLOPE (3/12)
NTS

0 (CODE)	CONCEPTUAL DESIGN (DESCRIPTION)				PROJECT/WCF NO.
KEYWORDS		DESIGN COMPANY: DBS&A			U.S. DEPARTMENT OF ENERGY ROCKY FLATS OFFICE GOLDEN, COLORADO
1.		DESIGNED BY			Rocky Flats Environmental Technology Site GOLDEN, COLORADO
2.		ABRAMS	CMA	12/21/01	
3.		DRAWN BY			PRESENT LANDFILL EVAPOTRANSPIRATION COVER DETAILS FOR WASTE RELOCATION OPTION
4.		BARTLETT	KDB	12/21/01	
5.		CHECKED BY			
BLDG/FACILITY		MILLER	MEM	12/21/01	
ROOM/AREA		APPROVED BY			
		McGOVERN	MFM	12/21/01	
		CLASSIFIER			SIZE: D
GRID COORD/ADJ. NO.	SCALE: NTS	CADLOAD			DRAWING NUMBER: FIGURE 13 ISSUE: 0

The primary disadvantage of covering the asbestos in-place is that significantly more cover soil is needed to complete the ET cover. The cover acreage is increased and the average cover thickness is substantially increased due to the wedge of soil needed over the east slope of the landfill, between the two asbestos disposal areas. The cover is over 50 feet thick in this wedge, as shown in cross-section A-A' in Figure 5. The soil quantities needed for cover construction to cover the asbestos in place are described in Section 3.4.

3.2.7.3 Relocate Asbestos

Relocating the asbestos into the main Present Landfill disposal cell, has the primary advantage of minimizing the area of the ET cover and substantially reducing the amount of soil required to complete cover construction. As discussed in Section 3.2.2.5, with relocation of the asbestos, a soil balance can be achieved for use of on-site soils regraded from the ET apron excavation area. Without relocation of the asbestos, a large quantity of soil must be imported from off-site, potentially raising additional transportation concerns. The soil quantities needed for cover construction with relocation of the asbestos are described in Section 3.4.

The primary disadvantage of relocating the asbestos is the potential impact on the project schedule that may result from the regulatory review process to complete the asbestos relocation. This issue has not been examined in detail as part of the ET cover conceptual design.

3.2.7.4 Decision-Making for Asbestos Options

The options for the asbestos disposal areas have been identified in the conceptual design effort as a key element of the project, which will require additional consideration for final decision-making. The asbestos options are discussed more fully in Section 3.4.1 on soil balance, and Section 9 on cost estimates. At this time, both options appear to be reasonable alternatives, therefore the conceptual ET cover design includes cover design configurations for both options.

3.3 Material Descriptions and Sources

A variety of soil and rock materials will be needed to construct the final ET cover. This section discusses the characteristics of materials needed for the various components of the ET cover

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and the most likely sources for these materials. Many potential sources of soil and rock materials exist, including both off-site commercial quarries and on-site borrow areas at RFETS. The preferred sources of materials are those that provide the needed materials in sufficient quantities and also help attain RFETS environmental restoration objectives. Final determinations of the suitability and source of materials will require additional investigation and testing of these materials and design optimization to accommodate the properties of available materials within the ET cover design.

Many of the materials for use in the soil-rooting medium, erosion protection, and methane-venting layers are available on-site. The conceptual design plans for the use of on-site materials to achieve multiple RFETS site closure objectives and provide a cost-effective design. Materials that will be obtained from off-site sources include synthetic materials used in the methane-venting system, seed mix, and possible soil amendments.

3.3.1 Previous Borrow Source Evaluation

A report entitled *Borrow Source Evaluation for Closure of the OU5 and OU7 Landfills* was prepared for the U.S. Department of Energy by EG&G Rocky Flats, Inc. (1994). The report addresses the Original Landfill (previously referred to as OU5) and the Present Landfill (previously referred to as OU7). This study examined potential soil borrow sources for final cover construction, based on a final cover design consisting of a 2-foot thick, low-permeability soil barrier layer, along with structural soil fill and topsoil. Both on-site and off-site borrow sources were considered, and material types and costs for a variety of potential borrow sources were compared. The report gives detailed consideration of off-site borrow sources, haul distances, and costs, and looks closely at existing commercial quarries.

The 1994 borrow source evaluation found that on-site soils were likely to provide the lowest cost construction, because the cost of transporting off-site materials quickly outweighs all other cost factors when haul distances reach more than a few miles. The report also raises the issue of royalty payments to the holders of mineral rights at RFETS.

3.3.2 *Soil-Rooting Medium and Erosion Protection Layers*

Performance modeling with UNSAT-H, discussed in more detail in Appendix A, shows that a minimum 18-inch thickness is required for the soil-rooting layer to support vegetation and to provide adequate soil moisture storage to prevent significant infiltration through the cover. The minimum thickness for the combined soil-rooting medium and erosion protection layers will be 30 inches, with an average thickness of approximately 50 inches, based on the cover layout design grades.

Typical rooting-medium soils for ET cover applications are sandy, silty, or clayey loams that contain significant fines (passing No. 200 sieve) to provide good moisture storage characteristics. The design thickness of the soil-rooting medium is variable depending on the moisture retention characteristics of the selected soils. An advantage of the ET cover is that a fairly wide range of rooting-medium soil properties may provide satisfactory performance.

Erosion rate calculations for the ET cover conceptual design using RUSLE are presented in Appendix F. The RUSLE erosion model was developed by the U.S. Department of Agriculture and is presented in Renard, et. al. (1997). In addition, independent erosion calculations are being completed by KH using the Watershed Erosion Prediction Project (WEPP) model.

The required thickness of the erosion protection layer varies depending on slope grades and lengths. Most of the cover requires a 6-inch-thick erosion protection layer. The steeper side slopes of up to 14 percent require a minimum 12-inch thick erosion protection layer to resist erosion over the 1,000-year design life.

The erosion protection layer is expected to consist of soils similar to the soil-rooting medium, with specifications for the size and percentage of gravel and cobbles. Rocky soils with appropriate characteristics may be identified that can be excavated and used directly for this purpose. For example, as discussed below, the soils available on-site at RFETS and from the nearby LaFarge Quarry show strong development and long-term stability. They also contain a large percentage of gravel and cobble-sized particles, making these soils well suited for the erosion protection layer. Alternatively, soils may be augmented with additional rock as needed.

Rock screened from on-site soils or from a variety of off-site commercial sources is suitable for this application.

Local soils possess the appropriate characteristics for the ET cover soil-rooting medium and erosion protection layer. The Flatirons Series surficial soils and Rocky Flats Alluvium in the shallow subsurface contain loamy soils with a significant clay fraction, which provide good moisture retention characteristics. The on-site soil and alluvium also contains a large fraction of cobble-size rock, which can be used to reinforce the upper erosion protection layer.

As indicated in a previous study (EG&G, 1994), a variety of soil borrow source locations may be considered as sources of suitable soil for construction of the ET covers over the Present Landfill. On-site and nearby soils at RFETS or off-site commercial quarries appear suitable based on initial laboratory testing and modeling results. Numerous factors must be considered in selecting the final soil borrow source, and final recommendations are not part of this materials report. Final decisions on the soil borrow source location will be made after material specifications are developed and more extensive soil testing is completed.

Additional subsurface investigation and geotechnical testing of potential soil borrow sources will be needed at the final design stage. Whatever final borrow source is selected, suitable soils will be available within reasonable haul distances to keep construction costs to a minimum. As recommended in the 1994 borrow source evaluation, competitive bids should be solicited either for off-site purchase and transportation or on-site excavation and regrading in order to obtain the most favorable terms.

Because the soil-rooting medium and erosion protection layers comprise the most significant material quantities in the cover, use of a nearby borrow source will minimize haul distances and provide cost advantages. With this in mind, two potential sources were examined: the nearby LaFarge Quarry and an on-site soil source. Both the LaFarge and on-site soils include the Flatirons Series soils and Rocky Flats Alluvium. On-site soils at RFETS in the vicinity of the Present Landfill are expected to have geotechnical and hydrologic properties similar to the soil tested from the LaFarge Quarry, which is described in more detail below. Soils at RFETS consist primarily of Flatirons Series soils developed on the Rocky Flats Alluvium, with lesser areas of Nederland and Veldkamp Series soils (Price, 1980). These soil types are described as very cobbly or very stony sandy loam. Flatirons soils are described as having low permeability due to significant clay, with rooting depths of 60 inches or more. Soil descriptions of these series are provided in Appendix G.

3.3.2.1 LaFarge Quarry Materials Source

An investigation was conducted to characterize, sample, and test the typical borrow soil available at RFETS for possible use in constructing the ET cover. Soil was sampled from the LaFarge Quarry adjacent to the northern RFETS boundary, where borrow soil may be obtained during cover construction. A total of nine samples were collected from a "select fill" soil stockpile at the quarry. The LaFarge Quarry select fill is the finer portion of soil remaining after larger cobbles and gravel are separated by screening for commercial purposes. It has minimal commercial value, and is used primarily to backfill excavations on-site.

The nine soil samples were tested at Advanced Terra Testing, Inc. (ATT) in Lakewood, Colorado. Samples underwent the following tests:

- Standard Proctor compaction
- Grain-size distribution (sieve and hydrometer)
- Saturated hydraulic conductivity
- Moisture retention characteristic curves
- Atterberg limits
- Consolidation
- Triaxial compression

One of the nine samples underwent verification testing at the DBS&A Hydrologic Testing Laboratories in Albuquerque, New Mexico. This testing involved two subsamples that were compacted to varying densities in the laboratory to simulate the typical compaction range experienced during construction activities. The soil is characterized as a sandy loam using the USDA Soil Classification and a clayey sand with gravel using the ASTM Soil Classification. A summary of the results are included in Appendix H.

The LaFarge Quarry soils tested represented the finer portion of the soil, with gravel and large-sized particles removed. Soil properties for typical on-site soils containing gravel and cobbles will need to be determined. On-site soils may also be processed to remove these large particles, if needed to satisfy final soil specifications. Gravel and cobbles removed from the soil-rooting medium may also be used to augment the cover's erosion protection or gas-venting layers.

3.3.2.2 Present Landfill Materials Source

The primary borrow source location being considered for closure of the Present Landfill is an on-site area located at the eastern edge of the Present Landfill. The conceptual design provides an option for a treatment area of approximately 6 acres east of the Present Landfill. The area will be recontoured as an extension of the Present Landfill ET cover and serve as an ET apron to eliminate the current seep at the eastern toe of the landfill (Figures 4 and 11). The recontouring will provide a source of sufficient soil quantities for ET cover construction over the Present Landfill, and the ET apron size and elevation can be designed to provide a soil balance to match excavation and cover soil quantities. Use of borrow materials from the ET apron can provide a cost-effective approach because of its proximity to the Present Landfill.

Several issues that need to be addressed in greater detail before moving forward with the use of on-site borrow materials include:

- Geotechnical investigation of the optional ET apron
- Determination of mineral royalty fees
- Permitting and environmental requirements

These issues will need to be addressed as part of the decision document for site closure and in the final design.

3.3.3 Coarse Aggregate

Coarse aggregate may be obtained from on-site soils or off-site commercial sources. Course aggregate is needed for two components of the ET cover:

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- Landfill gas-venting layer
- ET apron water distribution trenches

A fairly wide range of particle sizes may be suitable for these applications, ranging from pea-gravel to cobble-sized rock. Depending on the gas-permeability of the material, the gas-venting system design will need to be optimized to provide the appropriate pipe and vent spacing for the expected gas flow rates and most economical coarse material. Similarly, the ET apron water distribution trenches will require design optimization to establish trench spacing and sizing in conjunction with the permeability characteristics of the coarse aggregate.

Whether from on-site or off-site sources, the coarse aggregate is expected to be a processed material that has been screened to a specified size gradation. This type of screening operation can be cost effectively set up for short-term operation on-site, when significant quantities of aggregate are required.

3.3.4 Synthetic Materials

Synthetic materials used in the Present Landfill gas-venting system will be obtained from commercial, off-site suppliers. These materials need only limited longevity, until gas generation rates decline and waste is fully degraded. The synthetic materials used in the gas-venting layer include:

- Geotextile separation fabric
- High-density polyethylene (HDPE) piping (perforated, solid, and fittings)
- Landfill gas vents (HDPE, steel, or other materials)

Because many commercial providers of these materials are available, the costs are reasonable and competitive, and will be a minor portion of the overall construction costs. The conceptual design for the gas-venting system includes materials with typical geotextile strength, pipe sizing, vent types, etc.

3.3.4.1 Geotextile Separation Fabric

A geotextile separation fabric will be needed for construction of the gas-venting layer, to prevent fine particles from the overlying soil-rooting medium from clogging the coarse aggregate. A non-woven geotextile fabric, 8 to 12 ounces per square yard, or similar material, will fulfill this application. The geotextile separation fabric, with seams sewn to connect the fabric panels, will be placed over coarse aggregate.

Final design specifications for the geotextile separation fabric will depend on the particle-size gradation of both the underlying coarse aggregate and overlying soil-rooting medium. The appropriate geotextile strength will depend on the maximum particle size and particle angularity of the overlying and underlying materials. Tensile strength and elongation design requirements must also be considered to accommodate long-term waste settlement.

3.3.4.2 Piping and Vents

The methane-venting piping network will consist of perforated, 2-inch diameter, dimension ratio (DR)-17, HDPE pipe. Welded HDPE is the most common pipe material used for landfill gas collection systems due to its strength, flexibility, compatibility with landfill gas and condensate, and ability to withstand the forces of differential settlement over landfills.

The gas collection piping will be connected to a series of passive gas vent standpipes. The vent piping may be either HDPE or steel. The vents will need to be designed in a manner compatible with the planned open space land use and institutional controls that will be in place at the site. A U-tube vent that allows gas to escape and prevents entry of precipitation is the most common design. Vertical standpipes provide better gas-flow performance than U-tubes, because the chimney effect of wind movement across the standpipe creates a low-pressure driver to draw gas from the well. The small amount of precipitation that may enter a vertical standpipe is minimal within the overall cover water balance. A screen may be placed over the end of the vent, as needed, to prevent entry of animals or any foreign matter. A wind-driven turbine may also be added to the vent to increase air flow. Depending on the degree of public access and gas quality and emission rates, the vents may be extended to a height of 8 to 10 feet to minimize any gas exposure to the public and to avoid explosive accidents. Shorter 3-foot vents may be utilized if public access is restricted.

3.4 Material Quantities

Material quantities needed for construction of the ET cover have been calculated based on the conceptual design of final cover contours as shown in Figures 4 and 11. Soil and rock components make up a majority of the materials used in cover construction, and volume estimates for these materials are based on the design thickness of these components as shown in the cover details in Figure 6. The conceptual design provides reasonable estimates of the material quantities needed. The quantities will be refined during the final design process to optimize performance and cost factors.

3.4.1 Estimated Quantities of Materials for Construction

Material quantities for the construction materials described above are provided in Tables 6 [KA18](cover asbestos in place) and 7[KA19] (relocate asbestos). These tables provide details of the design assumptions used to estimate material quantities. In addition to the construction materials, several line items have been identified in the tables to show complete construction activities typically included in construction cost estimates. These items are described more fully in the construction cost estimate in presented in Section 9.

The material quantities provided are based on the conceptual cover design contours, and details are provided for assumptions made in determining quantities. During conceptual design, basic requirements for material properties, layer thicknesses, gas-venting system, and ET apron layout were planned using reasonable assumptions and dimensions. Further engineering design refinement and optimization will be needed to reach the final design stage.

3.4.2 Soil Balance

Designing for a soil balance is a critical element of a cost-effective design. Soil removed from the ET apron at the Present Landfill may be regraded over the Present Landfill. The two cover grading plan options shown in Figures 4 and 11 have very different soil balance outcomes, as summarized in Table 8.

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Table 6. ET Cover Material Quantities for Present, Cover Asbestos In-Place Option
Rocky Flats Environmental Technology Site

Item	Unit	Quantity	Description
Mobilization/demobilization	LS	1	Construction contractor and equipment mobilization and demobilization.
Construction staking	AC	42.8	Surveyor staking for construction grade control.
Clear and grub construction areas	AC	42.8	Remove vegetation from borrow and cover areas. On-site disposal at Present Landfill.
Excavation	CY	199,162	Excavation from on-site borrow source.
Soil processing/screening	CY	160,695	Screening rock on-site for erosion protection layer, gravel for landfill gas venting layer, and ET apron trenches.
Soil transportation, on-site	CY	360,127	Regrading from ET apron to Present Landfill.
Erosion protection layer	CY	50,870	Soil and rock placement and grading, minimum 12-inch thickness.
Soil rooting medium - on-site	CY	127,831	Soil placement and grading. Minimum 18-inch thickness, typically 2 to 3 feet.
Soil rooting medium - off-site	CY	247,510	Purchase from off-site source, 10 mile round trip haul, place w/dozer
Excavate — ET apron trenches	CY	3,970	Excavate trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — ET apron trenches	CY	3,970	Gravel filled trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — gas venting layer	CY	16,491	Placement and grading of processed gravel from on-site borrow, 6-inch thickness.
Perforated HDPE pipe — 2-inch diameter	LF	10,000	Gas venting passive collection piping, 100-foot spacing, 20.4 acres.
Solid HDPE pipe — 4-inch diameter	LF	4,675	Gas venting system pipe and fittings on landfill perimeter.
Revegetation	AC	47.1	Native seed mix, drill seeding, and soil amendment, includes additional 10% beyond construction limits.

LS = Lump sum
AC = Acre
CY = Cubic yards
ET = Evapotranspiration
HDPE = High density polyethylene
LF = Linear feet

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Table 7. ET Cover Material Quantities for Present Landfill, Relocate Asbestos Option
Rocky Flats Environmental Technology Site

Item	Unit	Quantity	Description
Mobilization/demobilization	LS	1	Construction contractor and equipment mobilization and demobilization.
Construction staking	AC	41.25	Surveyor staking for construction grade control.
Clear and grub construction areas	AC	41.25	Remove vegetation from borrow and cover areas. On-site disposal at Present Landfill.
Strip and stockpile	CY	18,187	Remove upper 12 inches of soil from borrow area and stockpile for cover
Excavation	CY	251,715	Excavation from on-site borrow source.
Soil processing/screening	CY	175,982	Screening rock on-site for erosion protection layer, gravel for landfill gas venting layer, and ET apron trenches.
Soil transportation, on-site	CY	427,697	Regrading from ET apron to Present Landfill.
Erosion protection layer	CY	42,665	Soil and rock placement and grading, minimum 12-inch thickness.
Soil rooting medium, on-site	CY	169,459	Soil placement and grading. Minimum 18-inch thickness, typically 2 to 3 feet.
Excavate — ET apron trenches	CY	3,970	Excavate trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — ET apron trenches	CY	3,970	Gravel filled trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — gas venting layer	CY	12,738	Placement and grading of processed gravel from on-site borrow, 6-inch thickness.
Perforated HDPE pipe — 2-inch diameter	LF	8,000	Gas venting passive collection piping, 100-foot spacing, 15.8 acres.
Solid HDPE pipe — 4-inch diameter	LF	3,911	Gas venting system pipe and fittings on landfill perimeter.
Excavation and relocating asbestos	CY	12,395	Excavation of asbestos and consolidation within the central landfill area, 10-foot depth, 0.8 acres.
Regrading solid waste	CY	32,800	Regrading waste and intermediate cover to reduce disposal cell height to improve cover slopes, 3.3-foot average depth, 8.4 acres.
Revegetation	AC	45.4	Native seed mix, drill seeding, and soil amendment, includes additional 10% beyond construction limits.

LS = Lump sum
AC = Acre
CY = Cubic yards
ET = Evapotranspiration
HDPE = High density polyethylene
LF = Linear feet

Table 8: Soil Balance Summary for the Present Landfill ET Cover

Cover Design Option	Soil Quantity Required [a] (cubic yards)	Soil Quantity Excavated from ET Apron [a] (cubic yards)	Net Import/Export (cubic yards)
Cover asbestos in-place	446,672	199,162	247,510 Import
Relocate asbestos	228,832	292,275	63,443 Export

[a] Total soil quantity includes erosion protection layer, soil-rooting medium, and gravel for gas-venting layer and ET apron flow distribution trenches.

The conceptual design grading plan requires a significant import of soil for the primary option to cover asbestos in place. The secondary option, to relocate asbestos, can create a significant excess of soil for possible export for other uses at RFETS. The secondary option can also provide a soil balance through adjustments to the grading plan to best meet the final design objectives.

The ET apron excavation quantity differs for the two options because the location and configuration of the ET apron changes for the two options, and the grading plan must change to tie-in the ET apron with surrounding native topography. Also, the size of the ET apron differs for the two options. For the primary option (covering the asbestos in place), the ET apron is 6 acres. For the secondary option, (relocating the asbestos), the ET apron was expanded to 7.5 acres in order to examine the potential to generate additional on-site soil. If the Present Landfill is addressed alone, the ET apron size and configuration may be optimized to achieve a soil balance.

The preliminary soil balance assumes that soil placed on the covers will have the same density as native soils removed from the on-site borrow source. However, a volume increase or swell factor of 5 to 10 percent may occur from excavated bank volume to in-place volume of placed soil. The final soil balance will need to be based on site-specific soil testing that reflects differences in density, so that such differences are accounted for in the final design.

The soil balance between borrow and fill areas can be adjusted as the design is refined and optimized in the final design process. Slight changes to the layout of the ET apron will provide flexibility in the soil borrow quantity. For example, raising or lowering the elevation of the ET apron by a few feet, or expanding the 6-acre apron area, creates substantial adjustments to the soil borrow quantity. Thus, the conceptual design approach incorporates a built-in mechanism to optimize the final design with regard to quantities and costs.

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4. Vegetation Plan

Control of infiltration through the proposed vegetated soil covers at the Present Landfill is key to an effective cover design. The current revegetation strategy at RFETS is to restore the native prairie grasslands as closely as possible to preexisting conditions. Considerable information on vegetation has been assembled by ecologists at RFETS, and this plan draws directly from revegetation guidelines for RFETS and from correspondence with the KH Ecology Group (KH, 2001).

4.1 Seed Mix

Seed mix will be procured from an off-site source based on seed specifications that meet KH Ecology Group requirements. Specific seedbed preparation, seeding, mulch application, and weed control should follow existing RFETS guidelines, and the revegetation plan should be prepared or reviewed by site ecologists. Because local native seed availability varies from year to year, the proposed mixture should be reviewed before seeding to reconcile any potential discrepancies between functional requirements and seed availability.

Native upland vegetation at RFETS varies from xeric tallgrass prairie to mesic mixed grass prairie. The largest portion of the tallgrass prairie is dominated by the native grasses *Andropogon gerardii*, *Muhlenbergia montana*, *Andropogon scoparius*, and *Stipa comata*, with *Koleria pyrimidata*, *Bouteloua hirsuta*, and *Bouteloua gracilis* also common. Another xeric grassland type is the needle-and-thread grass community, which is dominated largely by the native species, *Stipa comata*, with some occasional *Bouteloua gracilis*. The mesic mixed grassland is dominated by the native species *Agropyron smithii*, *Bouteloua gracilis*, *Bouteloua curtipendula*, and *Stipa viridula*. These communities should be specified in a final seed mix at the time of final design.

A mixture of warm and cool season plants should be used for effective control of infiltration. Cool season plants such as native western wheatgrass, green needle grass, and most forbs green up in early spring and rapidly transpire water accumulated in the soil profile during winter. Warm season plants, such as native grama and bluestem grasses, transpire more effectively

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during the warm summer months. Native prairies at mid-latitudes such as RFETS always have a mixture of both warm and cool season vegetation. The specified seed mix should be adaptable to microclimates such as those on north- or south-facing slopes.

A mixture of plants with varying rooting strategies and depths should be used. In general, cool season grasses have a more fibrous root system, while warm season vegetation is more deeply rooted. Root systems can make up 90 percent of a plant's biomass. The key vegetation design requirement is that available soil water will be fully used by the plant community during the growing season. The key soil requirement is that enough soil water storage be available to store precipitation while plants are dormant (approximately October to March). This is achieved by having roots actively uptake water at different depths and times, which means a mixture of warm and cool season grasses with varying rooting depths.

Plant cover must also provide erosion control. Site revegetation mixtures use a combination of warm and cool season grasses, as well as bunch and rhizomatous or sod-forming species. This combination has provided empirical on-site success. Native grasses at RFETS are both bunchgrasses and rhizomatous grasses. Native rhizomatous grasses include *Agropyron smithii*, *Bouteloua gracilis*, and *Buchloe dactyloides*. Native bunch grasses include *Andropogon gerardii*, *Andropogon scoparius*, *Stipa comata*, *Stipa viridula*, and *Bouteloua curtipendula*.

4.2 Soil Amendments

Soil amendments may be considered as an option to aid in establishing vegetation on the ET cover. If the erosion protection layer and soil-rooting medium are composed of a mix of both topsoil and Rocky Flats Alluvium, the material may be relatively poor in organic matter and nutrients. Testing for soil nutrients should be conducted and decisions made regarding the value of adding soil nutrient amendments to improve revegetation efforts.

Selection of soil amendments should be investigated more fully near the time of construction, because local availability of sludge, compost, and agricultural fertilizers can change rapidly depending on local government and commercial recycling programs. Possible soil amendments may include commercial fertilizer, compost, sewage sludge, manure, or other agricultural wastes. Avoiding unwanted introduction of weed seeds will be an important consideration in selecting soil amendments. Final recommendations for any soil amendments should be made in consultation with the KH Ecology Group.

4.3 Revegetation Plan for Cover and Disturbed Areas

All of the ET cover and any surrounding areas disturbed by construction activities will be revegetated. The optional ET apron, if used, will be revegetated as well. Revegetation activities will most likely take place as the last phase of construction activities; although revegetation may be postponed, if needed, depending on the season when construction is completed.

Initial establishment of vegetation will occur during the first year after seeding; however, it will take up to approximately five years for vegetation to become well established. When vegetation is fully established, plant roots will completely penetrate the ET cover erosion protection layer and soil-rooting medium. Only when vegetation is fully established, will the ET cover reach its full performance in minimizing infiltration.

Either drill-seeding or hydro-seeding may be considered, hydro-seeding is the method most commonly used for landfill revegetation efforts, because it is rapid and can work effectively on slopes. The ET cover slopes are gentle, and drill-seeding equipment can be operated on these areas as well. Due to the importance of vegetation on the ET cover, the best suited technical approach must be selected.

Small grass and forb seeds are often difficult to establish in semi-arid climates. Poor stands lead to longer establishment times and typically allow more wind and water erosion, as well as weed establishment, with attendant increased maintenance costs. Using a durable mulch to protect soil from erosion and to protect seedlings from desiccation would be advisable under conditions commonly experienced at RFETS.

Irrigation is an option for improved seed germination and establishment of plant stands on the landfill covers. Without irrigation, seeding may fail in dry years, which can result in additional establishment and maintenance costs. Depending upon the year, irrigation may be needed over large or small areas.

Water from the seep or from the landfill feeding the seep is a potential source of water. Seep water quality is more than adequate for irrigation and no irrigation will be done outside the footprint of the landfill. The decision to irrigate with seep water must be made at the time of seeding based upon soil and weather conditions. In most circumstances, a single season of irrigation is likely to be adequate. Under severe drought conditions, irrigation may need to be extended.

Existing RFETS revegetation guidelines are consistent with the functional objectives discussed above. Specific seedbed preparation, seeding, mulch application, and weed control should follow existing guidelines, and the revegetation plan should be prepared or reviewed by site ecologists. Previously used seed mixes will effectively meet the objectives discussed above. Because local native seed availability varies from year to year, the proposed mixture should be reviewed before seeding to reconcile any potential discrepancies between functional requirements and seed availability.

5. Erosion Control

The materials used in the ET cover consist primarily of native soil, gravel, and rock, which are not subject to significant long-term degradation and will meet the project design criteria for a 1,000-year design life. The soil-rooting medium and erosion protection layer consist entirely of this native, non-degradable material. Use of native vegetation will stabilize the cover soils in a manner that is expected to provide longevity and adaptability to environmental changes. As observed on-site, native vegetation promotes the formation of stable soil horizons.

The cover slopes must be designed to resist erosion to the extent that the design criterion for cover longevity is achieved. A design life of 1,000 years may be applied to the site based on RFETS objectives. Erosion resistance is improved by reducing cover slopes; however, this will lead to the eastern landfill slope impinging on the East Landfill Pond and wetlands.

The required thickness of the erosion protection layer will vary depending on slope grades and lengths. Most of the cover requires a 6-inch thick erosion protection layer. The steeper side slopes of up to 14 percent require a minimum 12-inch thick erosion protection layer to resist erosion over the 1,000-year design life. Erosion resistance will be enhanced by use of selected vegetation and rock armoring.

5.1 Soil Erosion Evaluation

Erosion rates were calculated for a range of cover slopes. The final determination of the maximum slope that can achieve the required erosion resistance and longevity, will dictate the extent to which the cover extends east of the landfill toward the East Landfill Pond.

The RUSLE model was used to calculate slope erosion for RFETS. RUSLE is a widely used model to predict soil loss on any field condition where soil erosion by water is possible (Renard, et al., 1997). Erosion rates were modeled for the cover configuration as shown on the landfill cover grading plan (Figure 4). The slope length and gradient were measured for several of the key transects on the Present Landfill and a range of values was used to examine erosion rates on varying slopes. (Figure 5).

Erosion modeling used site-specific values based on properties of the Flatirons Series soil at RFETS and climatic data for the Denver area. Model input parameters for erosion-index and the rainfall-runoff erodibility factor factors were derived from the isoerodent map for Colorado (Wischmeier, 1978) and the Agriculture Handbook #703. The RUSLE model uses these inputs to determine the erosion force of a specific rainfall event. Erosion losses from rainfall are calculated for the maximum 30-minute rainfall intensity.

As discussed in the storm water management plan (Section 6), the soil permeability is a key element affecting the amount of runoff generated during heavy precipitation events. The saturated hydraulic conductivity of potential off-site borrow soil for the soil-rooting medium was calculated from testing as 0.72 in/hr, and this value was used in the RUSLE erosion model. This value is conservative from the standpoint of predicting higher erosion rates. The final erosion protection layer surface soil will contain a significant amount of rock and gravel to have a permeability exceeding the permeability of the soil-rooting medium. Based on the runoff calculations in Appendix I, runoff is minimized for a surface soil permeability of approximately 3 in/hr or greater. Therefore, erosion may be controlled to a greater extent by selecting appropriate properties for the erosion protection layer for long-term erosion control performance exceeding the RUSLE model predictions.

The RUSLE soil erosion model allows for the input of local plant community characteristics, which was specified in the model as a short-grass prairie. It is assumed that after being established, the plant community will have a relatively constant amount of canopy cover, surface and subsurface residues, and root mass. The percent of surface covered by rock fragments was also used as input to the RUSLE model. The model inputs were consistent with published values for undisturbed rangeland.

The results for the RUSLE soil erosion modeling are provided in Appendix F. Using conservative input parameters, it will take approximately 1,400 years for 1 foot of soil to erode from the landfill on the steeper slopes (14 percent). The model was used to predict erosion from the existing east slope of the Present Landfill, which has a slope of approximately 30 percent. This steep slope will experience 1 foot of erosion in approximately 870 years, which is consistent with field observations indicating considerable gullying on this slope. The conceptual design reduces the east slope of the Present Landfill final cover considerably to minimize erosion and improve cover longevity.

5.2 Provision and Plan

Plans for erosion control have been evaluated through erosion rate modeling to demonstrate the feasibility of the ET cover to provide 1,000-year longevity. Provisions to minimize soil erosion are addressed by the ET cover conceptual design in the following ways:

- The cover grading plan for the landfill provides gentle slopes of 3 to 14 percent to minimize erosion.
- A 6-inch minimum and 12-inch maximum erosion protection layer will be constructed on the entire surface of the ET cover.
- The erosion protection layer will specify a significant fraction of rock and gravel-sized particles to resist both storm water and wind erosion.
- Well-established vegetation will stabilize the soil and prevent erosion.

The storm water management plan for the Present Landfill can handle intense storm events with minimal runoff and little impact to surrounding areas or the site-wide surface control system at RFETS. The plan reduces runoff to the extent that erosion can be controlled and long-term maintenance is eliminated.

5.3 Sediment Control During Construction

During construction, sedimentation due to storm water runoff must be controlled and standard sediment reduction practices will be required. These may include such measures as temporary sediment control (silt) fencing, diversion berms and/or catchment basins. Such structures will need to be inspected and maintained throughout the course of the construction. Some sediment control measures may also need to be maintained throughout the first year after construction has been completed, until adequate vegetation has been established to eliminate a need for further sediment controls.

6. Storm Water Management Plan

The storm water management plan for the Present Landfill ET cover is based on minimizing runoff and establishing a final cover that behaves very much like the undisturbed native grasslands at RFETS. The predominant performance consideration for the storm water control system is to minimize erosion to meet the design criterion for 1,000-year longevity. To meet this design life, storm water is controlled by dispersed, overland flow, rather than focusing flow in engineered storm water channels. Storm water will flow off of the ET cover on gentle grades ranging from 3 to 14 percent at the landfill. Storm water runoff from the gently sloping, vegetated ET cover will be nearly the same as runoff from the surrounding landscape. Runoff from the ET cover will not be impacted by contaminants and will be handled within the overall RFETS storm water control system.

6.1 Storm Water Design Approach

The conceptual design approach for storm water management is unique, since the ET cover promotes infiltration of storm water and minimizes runoff. Conventional runoff channels and detention basins are not part of the storm water design approach. The site grading plan has been designed to shed storm water relatively uniformly around the entire ET cover, eliminating any focused or channelized flow. Overland flow from the cover will be dispersed to surrounding areas and will not come in contact with waste materials or residual contaminants.

The ET cover design encourages infiltration in two ways:

- Topsoil is highly permeable
- Vegetation reduces downslope flow

Long steep slopes with native vegetation at RFETS show minimal erosion. The use of permeable, vegetated soils will allow infiltration of most precipitation and eliminate runoff in all but the most severe storm events.

The storm water management plan for the ET cover provides significant advantages over a conventional storm water control system that uses conveyance channels and detention basins. The conventional engineered design must overcome the following obstacles to meet the 1,000-year design criterion:

- Conveyance channels and detention basins must be sized for a 1,000-year or greater design storm
- Concrete structures cannot be used, because exposed concrete will degrade over time
- Structures must be oversized to the extent necessary to accommodate sedimentation
- Planned maintenance, typical of most engineered storm water systems, cannot be included in the design

The ET cover storm water management plan eliminates the need to address these issues.

The ET cover will shed relatively minor storm water runoff, which will be captured in the RFETS surface water management basins, downstream in No Name Gulch. Calculations for the amount of runoff expected are provided in the following section. Input parameters to the runoff calculation model were consistent with native terrain, which will be closely simulated by the ET cover.

6.2 Runoff Calculation Methods

Storm water runoff from the ET cover was calculated using two methods: (1) the Rational Method and (2) the Colorado Urban Hydrograph Procedure (CUHP). These runoff models use characteristic values for calculation that have been determined to be reasonably representative of local conditions. Each of the calculation methods is described below, followed by a discussion of the results.

6.2.1 Rational Method

The Rational Method is widely used for modeling small watersheds. Rational Method calculations used the Denver Urban Drainage and Flood Control District (DUDFCD) spreadsheet to automate the calculations and provide regional constants. Results of the spreadsheet calculation include:

- Computed time of flow concentration
- Regional time of flow concentration
- Rainfall intensity (in/hr)
- Peak flow rate (cubic feet per second [cfs])

The Present Landfill area was divided into six sub-basins based on slope and direction of overland flow, and the average flow path length and slope were determined for each of the six sub-basins. Sub-basin areas range from 1 to 12 acres at slopes of 4 to 14 percent. Soil and vegetation parameters representative of the ET cover design were selected to simulated native vegetation over soils that exhibit minimal compaction for good infiltration capacity.

Storm water runoff was calculated for design storms with return periods of 100 and 1,000 years. Maximum runoff was calculated for the most intense 1-hour storm events, which are representative of extreme downpours. The one-hour precipitation for the 100-year storm was determined to be 2.7 inches from the 100-year, one-hour rainfall chart included in the DUDFCD *Drainage Criteria Manual* (DUDFCD, 2001). To determine the 1-hour precipitation value for a 1,000-year storm, the one-hour precipitation values from the 2-, 5-, 10-, 25-, 50-, and 100-year charts were graphed, and the 1,000-year, 1-hour precipitation value was extrapolated to be 3.7 inches. For the landfill, peak runoff rates of 59 cfs and 80 cfs were calculated for the 100-year and 1,000-year storm events, respectively.

6.2.2 Colorado Urban Hydrograph Procedure

The CUHP is a method of hydrologic analysis based on the unit hydrograph principle. It has been developed and calibrated using rainfall-runoff data collected in Colorado (mostly in the Denver/Boulder metropolitan area). The CUHP method differs significantly from the Rational Method in that soil infiltration rates may be selected by the modeler. In this case, an infiltration value of 3 in/hr was selected, which is in the range expected for the ET cover erosion protection layer.

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Storm water runoff was calculated by the CUHP method for the same 100- and 1,000- year design storms with maximum runoff from intense 1-hour storm events. Again, these 1-hour storm events were assumed to result in 2.7 and 3.7 inches of rain, respectively. The peak runoff rate for the landfill was calculated as 1 cfs for the 100-year storm, while the peak runoff rate was calculated at 48 cfs for the 1,000-year storm.

6.2.3 Discussion of Results

As seen above, predicted storm water runoff flow rates vary widely between the Rational Method DUDFCD spreadsheet and the CUHP. The Rational Method uses a generalized input to characterize soil and vegetation properties, while the CUHP model uses direct input of the soil infiltration rate. The model results are very sensitive to this input, and thus, give very different results. Runoff model results are summarized in Table 9.

Table 9: Summary of Runoff Calculations for the Present Landfill ET Cover

Storm Event Recurrence Interval	1-Hour Design Storm Precipitation (in/hr)	Area (acres)	Peak Flow Rate (cfs)
Denver Urban Drainage and Flood Control District (DUDFCD) Rational Method Spreadsheet			
100-year	2.7	43.7	58.8
1,000-year	3.7	43.7	80.2
Colorado Urban Hydrograph Procedure (CUHP)			
100-year	2.7	43.7	1
1,000-year	3.7	43.7	48

The CUHP model demonstrates the effect of soil permeability on runoff flow rates. Sufficient surface soil permeability allows nearly complete infiltration of all precipitation from a 1-hour, 100-year storm event. Only the rare 1,000-year storm event leads to significant runoff. Nearly all of the precipitation from smaller storm events will infiltrate, and will provide soil moisture to sustain the ET cover vegetation. While the two methods of calculation give significantly different results, the most credible evidence to guide design is the presence of similar stable native slopes nearby with the same soils and vegetation.

6.3 Provision and Plan

The storm water management provisions for the ET cover will be addressed not only through engineering design features, but also with careful consideration of soil and vegetation properties to minimize storm water runoff. The conceptual design includes the following storm water provisions:

- The cover slopes are 3 to 14 percent.
- Cover grades are crowned outward (convex) to disperse and distribute overland flow and shed water to surrounding areas.
- Areas of focused or channelized flow are eliminated.
- The erosion protection layer will have sufficient permeability to infiltrate nearly all precipitation and minimize runoff
- ET cover vegetation will be supported by capturing precipitation with the vegetation further controlling runoff and erosion.

Based on the modeling, the proposed storm water management plan for the Present Landfill can handle intense storm events with minimal runoff and little impact to surrounding areas or the site-wide surface control system at RFETS. The storm water management plan reduces runoff to the extent that erosion can be controlled and long-term maintenance is eliminated.

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7. Monitoring Plan

The overall monitoring approach will use a phased program of action monitoring and performance monitoring. A phased approach allows more intensive monitoring in early years during vegetative establishment and characterization of the newly engineered system. Monitoring intensity will decrease over time as understanding of system behavior increases. Performance monitoring is driven by RFCA-imposed standards based primarily on surface water standards. The purpose of action monitoring is to anticipate performance failure before it happens. Thus, action monitoring of the cover should provide information on water storage and movement in the installed final cover to determine if there will be a negative impact at the performance monitoring locations.

7.1 Phased Monitoring Program

During Phase I intensive monitoring, a relationship will be established between the water balance in the cover and RFCA performance. Phase II will link visual observations of vegetation to the cover water balance through water-potential monitoring and numerical modeling. Vegetation and water-potential monitoring will continue on the covers and the grassland locations. Phase III, if needed, will continue system performance monitoring, maintenance, and vegetation monitoring as needed for a duration to be determined at the end of Phase II.

7.1.1 Action Monitoring

The simplest and most useful monitoring on the cover is a basic inspection and maintenance program. This program will start following completion of the final cover. Testing and inspection of the cover will include as-built sampling of the covers, periodic visual inspection of surface water controls, vegetation quality, weeds, seepage, burrowing animals, subsidence, and erosion. As-built soil sampling of the covers for physical and hydraulic properties will include bulk density, particle size, water-holding capacity, and hydraulic conductivity. The maintenance program will include weed control using mowing and/or herbicides, reseeding of bare areas, filling and regrading of subsidence zones to maintain positive drainage, and repair of eroded areas or storm water control features. A separate and detailed inspection and maintenance schedule for the site will be developed during the final design phase of the project.

Action monitoring consists primarily of monitoring components of the cover water balance. The information from action monitoring is used to assess the hydrologic performance of the cover based upon in situ measurements of soil properties and water and gas fluxes. This hydrologic performance assessment is used, in turn, to support attainment of RFCA performance standards. Monitoring of the cover water balance at the Present Landfill will include measurement or calculation of soil water content, soil-water potential, unsaturated water flux, temperature, and soil gas composition. Weather data will be collected on-site and will be available throughout the monitoring period.

7.1.2 Performance Monitoring Locations

For RCRA units, monitoring should occur at or near the boundary of the unit. Point(s) of compliance (POCs) being considered at the Present Landfill include performance monitoring locations at the toe of the regraded east slope near the existing seep. Surface water flow at the seep will be quantified and water quality monitored. In accordance with RFCA Attachment 10, Page 10-1, final POCs will be determined after the cap/cover has been installed.

7.1.3 Methane Monitoring

Landfill gas monitoring is considered an option to the monitoring program, which may be needed to meet RFETS air quality requirements. The landfill gas monitoring is not necessarily a fundamental component of the primary monitoring program aimed at determining the ET cover infiltration reduction performance. Potential landfill gas air quality impacts have not been evaluated as part of the ET cover conceptual design, but a more detailed determination of the regulatory requirements for possible landfill gas monitoring should be undertaken.

If needed, the landfill gas vents provide monitoring locations where landfill gas may be sampled. Small sampling ports may be installed in the gas vent standpipes to allow simple sample collection. Because diurnal and barometric pressure changes affect the flow of landfill gas out of the landfill and air flow into the landfill, a time-weighted monitoring approach is needed to characterize the overall gas concentrations and air emissions over time. Landfill gas measurements should be collected periodically over the course of one or more days, and the time of sampling recorded; alternately, dedicated instruments may be set up with dataloggers to continuously record gas concentrations over a period of days.

Primary landfill gas monitoring is generally conducted with field instruments that measure concentrations of methane, carbon dioxide, and oxygen. A limited number of laboratory verification samples may be collected in Tedlar bags for analysis of these parameters using EPA method 3C. Testing for NMOCs, VOCs, and/or HAPS is conducted by laboratory methods. Landfill gas samples for these organic constituents are collected in Summa canisters to preserve sample integrity.

Monitoring for landfill gas concentrations within the ET cover soil may be added to the monitoring program as an option if portions of the Present Landfill ET cover appear to show signs of stressed vegetation, which may be caused by a poorly oxygenated root zone. Soil gas samples can be collected by driving a small diameter (¼- to ½-inch) soil gas sampling probe into the soil to collect gas samples through a slotted tip. Both manually operated and automated probe systems are available. The soil gas investigation will most likely be interested only in field measurement of methane, oxygen, and carbon dioxide concentrations. When driving the probe, care is needed not to penetrate the gas-venting layer and the geotextile filter fabric at the top of the layer. The depth to the gas-venting layer will be variable across the cover.

7.2 Instrumentation

7.2.1 Heat dissipation sensors

Heat dissipation sensors (HDSs) will be used to monitor soil-water potentials and temperatures and also can be used to calculate water storage, percolation, and soil water content, and temperature gradients. HDSs infer soil-water matric potential from thermal conductance measurements of a ceramic matrix that is in hydraulic equilibrium with the surrounding soil

(Campbell et al., unpublished manuscript). The water potential range is approximately -0.2 to -100 bar with a sensitivity that is proportional to water potential.

7.2.2 Time-Domain Reflectometers

The process of sending pulses through a cable and observing the reflected waveform is called time-domain reflectometry (TDR). The type of material surrounding the conductors influences a waveform traveling down a coaxial cable or waveguide. If the dielectric constant of the material or medium surrounding the conductors is high, the electronic signal propagates more slowly. Because the dielectric constant of water is much higher than most materials, a signal within a wet or moist medium propagates slower than in the same medium when dry. Ionic conductivity affects the amplitude of the signal but not the propagation time. Thus, moisture content can be determined by measuring the propagation over a fixed-length probe embedded in the soil medium being measured.

A major advantage of TDR for soil moisture content measurement is the ability to fully automate the system. Additionally, once installed the system can have a long life span. Accuracy in many soil types is very good. A TDR system's accuracy, in general, is about the same as that for neutron probes (Schofield et. al., 1994).

Recent developments in TDR instrumentation have resulted in a TDR unit that connects directly to a datalogger. Calibration similar to the traditional TDR system is required for best results. This TDR water content reflectometer consists of two stainless steel rods connected to a printed circuit board. A five-conductor cable is connected to the circuit board to supply power, activate the probe, and monitor pulse output.

Oxygen will be monitored in the profile using Figaro KE-25, or similar sensors. LFG measurements showed that parts of the existing intermediate cover are low in oxygen. Five sensors will be installed in each of the two monitored cover profiles.

7.2.3 Lysimeters

Soil lysimeters are used for collecting deep drainage or percolation data and estimating recharge. The most commonly used lysimeter in covered systems is a simple variation of the soil lysimeter called a pan lysimeter. The pan lysimeter is an impervious pan installed beneath or within the soil in the plot of interest. Water collected in the pan drains to a collection system where it is subsequently quantified. There are numerous designs of lysimeters, however, they are typically less than 6 feet in depth. Fort Carson lysimeters are 4.5 feet in depth and RMA lysimeters vary from 3.5 to 5 feet in depth. The rate of soil water collected per unit area monitored is extrapolated and used to estimate the percolation rate of the entire cover system.

Lysimeters are not recommended at the Present Landfill because methane levels are high enough to affect rooting depths, transpiration rates, and cover performance. A lysimeter located away from the landfill would not be subjected to landfill gases and satisfactory lysimeter performance would not be indicative of final cover performance or provide an alert to possible performance failure of the system. Similarly, because lysimeters are sealed on the bottom, a lysimeter installed on the final cover would not be subjected to landfill gas flux. Thus, lysimeters would provide a misleadingly optimistic assessment of performance at the Present Landfill.

7.3 Monitoring Phases

Required performance monitoring at the Present Landfill is based upon a surface water standard (RFCA, Attachment 10). The cover system conceptual design will reduce infiltration through the cover by increasing transpiration and maintaining positive drainage. The intent is to meet performance requirements by eliminating all seepage from the landfill.

The seepage rate currently averages 2-3 gallons per minute (gpm) at the toe of the east slope of the landfill. For long-term erosion stability, the east slope of the landfill will be reduced to 14 percent. This reduction of the eastern slope will move the expression of any surface water several meters farther east, and the surface water monitoring location will be moved to correspond to the first surface appearance of water. In addition, the evapotranspiration apron below the landfill will be monitored for surface water and seeps. The facility will be observed for

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surface water on a quarterly basis and all observed locations of surface water will be sampled separately and tested as specified in RFCA.

7.3.1 Phase I: Intensive Monitoring, First 6 Years

Phase I will require a minimum of six years of data collection after vegetation is established on the cover. The intent of the Phase I effort is to obtain an understanding of the cover water balance and to gain understanding that will aid in the transition to a simple, cost-effective, long-term monitoring plan. A Phase I final report will be prepared within six months after completion of the six-year data collection period, and will include a data summary and interpretation, and a recommendation on whether to proceed to Phase II.

Standard inspections will be made monthly for the first two growing seasons following emplacement of the final cover (during establishment of vegetation), and quarterly for the last four years of this phase. Inspections will include observations of differential settlement, ponding, erosion, or changes in vegetation. Inspections for erosion will also be conducted after major precipitation events.

Action monitoring of the cover will provide information on water storage and movement. The information from action monitoring will be used to assess hydrologic performance of the cover. The information needed for this objective at the Present Landfill will be obtained from in situ soil measurements.

The as-built soil properties will be measured to determine relationships between soil water potential, soil-water content, and unsaturated hydraulic conductivity. Soil-water potential profiles and temperature profiles will be monitored using nested heat dissipation sensors. TDR probes will also be installed to obtain redundant information on water movement and storage within the profile.

HDSs will be installed following final cover construction at approximately 12-inch intervals within the cover and in the underlying waste. Two sets of HDSs will be installed on the Present Landfill cover, consisting of eight sensors each. Another set of HDSs will be installed near the seep monitoring location and will consist of eight sensors. Temperature and soil-water potential data will be collected daily using Campbell 23X dataloggers. Soil hydraulic and thermal properties of the cover will be measured or calculated from field and laboratory data.

TDR sensors will be placed at the same depths as HDS installations. These probes will provide independent information on performance (water content) in the cover profile and the ET apron.

Free oxygen is needed to sustain root growth and transpiration. Therefore, oxygen levels in the cover and the venting layer will be monitored at the two cover monitoring locations using Figaro KE-25 (or similar) oxygen sensors. Monitoring of oxygen levels may be discontinued when it is established the venting layer is functioning as designed.

7.3.2 Phase II: Intermediate Monitoring, Years Six 6 through 10

Phase II will continue all inspection and maintenance activities of Phase I. Observed infiltration through the ET cover during Phase II is anticipated to be near zero. Monitoring of the HDS and TDR profiles in the cover and seep monitoring location will be discontinued. Quarterly performance monitoring will continue with automated water level measurements and water quality sampling. The results of Phase II will be a data summary and interpretation, including an evaluation of the relationship between vegetation, soil, and infiltration, and an evaluation of the stability of the system at the ten-year monitoring period.

7.3.3 Phase III: Long Term Monitoring, Years Ten 10 through 30

Phase III will continue the inspection and maintenance activities of Phases I and II. Observed infiltration through the ET cover during Phase III should continue to be zero. Annual performance monitoring will continue with automated water level measurements and water quality sampling. The results of Phase III will be a data summary and interpretation, including an evaluation of the relationship between vegetation, soil, and infiltration and an evaluation of the stability of the system at the end of the 30-year monitoring period.

8. Constructibility Evaluation

The conceptual design of the Present Landfill cover provides for standard construction methods. The earthwork, aggregate placement, piping installation, geosynthetics installation, and revegetation associated with construction of the cover are all practices that are common in the U.S. construction industry. This constructibility evaluation examines all components of the design to ensure the cover can be properly built in an efficient and effective manner.

A key factor in the construction schedule and approach will be whether on-site or off-site soil borrow sources are selected. The construction methods and equipment will vary depending on whether on-site excavation is needed and on the means of soil transport, whether with on-site haul vehicles or trucks from off-site sources. Access routes and transportation plans to haul soil from off-site sources is a key constructibility issue if large soil quantities for the major cover components are imported. This section addresses several alternatives for on-site and off-site borrow soil sources

8.1 Material Sources

A variety of potential sources of soil and rock materials exist, including both off-site commercial quarries and on-site borrow areas at RFETS. Final material selections should provide sufficient material quantities and also help to attain RFETS environmental restoration objectives. Use of on-site materials can benefit the RFETS environmental restoration process in the following ways:

- Recontouring of an ET apron east of the Present Landfill will provide needed soil and rock while simultaneously addressing several technical environmental restoration challenges.

- Revegetation of the ET covers with native species will provide infiltration reduction, assurance of longevity, and compatibility with the surrounding environment.

Final determinations of the suitability of on-site materials will require additional investigation and testing of these materials and design optimization to accommodate the properties of available materials within the ET cover design.

A detailed off-site borrow source investigation has been conducted and suitable soil located. Depending on the final design configuration, borrow materials may come from on-site, off-site, or a combination of on- and off-site sources.

8.1.1 Material Availability

On-site soils possess the appropriate characteristics for the ET cover soil-rooting medium and erosion protection layer. The Flatirons Series surficial soils and Rocky Flats Alluvium in the shallow subsurface contain loamy soils with a significant clay fraction, which provide good moisture retention characteristics. The on-site soil and alluvium also contains a large fraction of cobble-size rock, which can be used to reinforce the upper erosion protection layer.

Materials that may be obtained from off-site sources include synthetic materials used in the methane-venting system, seed mix, and possible soil amendments. Synthetic materials used in the Present Landfill gas-venting system will be obtained from commercial, off-site suppliers. The synthetic materials used in the gas-venting layer include:

- Geotextile separation fabric
- HDPE piping (perforated, solid, and fittings)
- Landfill gas vents (HDPE, steel, or other materials)

Because many commercial providers of these materials are available, the costs are reasonable and competitive, and will be a minor portion of the overall construction costs. The conceptual design for the gas-venting system includes materials with typical geotextile strength, pipe sizing, vent types, etc.

Seed mix and possible soil amendments will be procured from off-site sources based on seed specifications and soil nutrient needs. Seed mix specifications must meet KH Ecology Group requirements, with consideration of the seed species that can be reasonably obtained. Testing for soil nutrients should be conducted and decisions made regarding the value of adding soil nutrient amendments to improve revegetation efforts. Selection of soil amendments should be investigated more fully near the time of construction, because local availability of sludge, compost, and agricultural fertilizers can change rapidly depending on local government and industrial programs.

8.2 Geotechnical Site Investigation

A geotechnical site investigation of the proposed soil borrow source is needed to determine soil properties for final design. A series of soil borings will be needed across the borrow area, whether on-site or off-site, to obtain samples for laboratory testing and determine subsurface characteristics. This section describes general requirements for the geotechnical site investigation drilling program, with approximate numbers of soil borings, depths, and test requirements. Final plans for the geotechnical investigation will be made during the final design stage.

The geotechnical investigation described in this section focuses primarily on the Present Landfill ET apron soil borrow area, but may also be adapted to other areas at RFETS or to off-site borrow locations. If soil is obtained from an off-site commercial source where sufficient material testing has already been conducted, a geotechnical site investigation will not be required. In this case, detailed material specifications will be needed, in combination with appropriate conformance testing to demonstrate compliance with the specification.

The geotechnical site investigation at the on-site Present Landfill ET apron or other potential RFETS on-site soil borrow area will examine the following issues:

- Thickness of Rocky Flats Alluvium
- Depth to bedrock
- Depth to the water table
- Possible presence of soil or groundwater contaminants

The site investigation should be coupled with KH efforts to evaluate the groundwater intercept system at the Present Landfill.

Soil samples should be collected from the Rocky Flats Alluvium for laboratory testing of geotechnical and hydrologic properties. These tests are anticipated to include, at a minimum:

- Standard Proctor compaction
- Atterberg limits
- Grain-size distribution (sieve and hydrometer)
- Internal shear strength
- Cohesion
- Moisture retention characteristic curves
- Saturated hydraulic conductivity
- Dry bulk density
- Porosity
- Particle density
- In situ moisture content

Because cobbles too large to be included in conventional sampling by driven split-spoon samplers are present in RFETS soils, cobble percentages should be described and quantified by observation of drill cuttings. The size-range of cobbles, coupled with laboratory grain-size data, will be important in determining soil suitability for erosion protection. The importance of cobbles in the design will require a relatively large-diameter drill. Hollow-stem auger drilling will satisfy most requirements of this project, although other drilling methods may also be evaluated. Additional large-diameter borings or test excavations will be needed to adequately characterize the fraction of large rocks that cannot be sampled with a hollow-stem auger.

Soil borings should be drilled through the alluvium and into the uppermost portion of the underlying bedrock. Bedrock underlying the site consists of undifferentiated sandstone, siltstone, and claystone of the Arapahoe and Laramie formations (KH, 1996). During drilling, soil samples should be collected using split-spoon samplers at a minimum of 5-foot intervals. Material descriptions should be recorded by a qualified geologist and a Standard Penetration

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Tests should be recorded along with sample collection data. Split-spoon sampling will confirm that the borings have fully penetrated the alluvium and that the uppermost bedrock has been reached.

All borings should be plugged and abandoned by fully grouting the borings from bottom to top. Grout should be emplaced by pumping it through a tremie pipe as the auger flights are removed. Grout should be injected until it reaches the surface, then topped off as necessary one or two days later. The grout may be a cement slurry with a bentonite amendment or a pure bentonite gel. Bentonite gel has the advantage of minimizing any affects on the borrow soils when they are excavated for cover construction.

A series of approximately 20 to 40 soil borings are expected to adequately characterize site conditions. Across the potential borrow area, the thickness of the alluvium is expected to range from approximately 5 to 30 feet in thickness. The site investigation will determine the depth to bedrock and allow accurate calculation of available borrow soil quantities.

The lower portion of the alluvium is saturated, and accurate water table elevation data will be gathered during the investigation. These data will be very important for final excavation plans and the design of dewatering systems for excavation, if needed. The water table elevation will also be an important design consideration for the design of a constructed ET apron. As needed, monitor wells or piezometers may be installed in soils to provide additional water level data or to collect water quality samples.

8.3 Construction Methods

Construction methods for each of the components in the ET cover conceptual design are straightforward and follow common industry practice. The majority of the construction effort will be earthwork to place the soil-rooting medium, erosion protection, and aggregate layers. The construction methods required for the Present Landfill ET cover are described in the following sections.

8.3.1 Clearing and Grubbing

All areas where the cover will be placed and areas of excavation for soil borrow will be cleared and grubbed prior to starting earthwork. Existing vegetation should be stripped in order to provide consistent adhesion between the existing soils and the overlying soil materials place for cover construction. This is particularly important on the eastern slope of the Present Landfill, where steep slopes of approximately 30 percent currently exist. Clearing and grubbing this slope will avoid creating a potential slippage plane along a layer of matted vegetation. Likewise, vegetation should be stripped from the surface of soil borrow areas to provide consistent borrow soil and avoid irregular amounts of plant material mixed with the borrow soil.

A suitable means of disposal will need to be determined for the vegetation and soil generated by clearing and grubbing. The possibility of contaminants in the material may need to be considered and could affect disposal alternatives. At the Present Landfill, where organic solid wastes have been disposed, it appears suitable to place and compact the clearing and grubbing spoils on a portion of the landfill where additional fill may be useful to reach final design grades. The spoils will exhibit properties much like the rest of the solid waste mass in the landfill and will not affect the ET cover.

8.3.2 Grade Control

Control of construction grades is needed throughout the project using conventional surveying techniques. Grade control provides for proper placement of all materials used in construction and construction according to the final design plans. Independent survey verification should be used to spot-check grades and material thicknesses as a quality control measure. The grade control survey also provides as-built quantity determinations for payment to the construction contractor.

8.3.3 Soil Excavation

Soil excavation will be an important element only if an on-site borrow source such as the ET apron is selected. For off-site borrow sources, only very minor, if any, excavation will be needed in the course of tie-ins to existing ground surface.

If an on-site borrow source is selected, excavation may be accomplished using:

- Scrapers with direct haul to the placement location
- Track-hoe excavator(s) and haul trucks
- Farm-type tractors with scraper trailers

The contractor's choice of excavation equipment will depend on the proximity between the borrow source and placement location and on the geotechnical characteristics of the on-site soil. Ripping of the soil using bulldozer(s) may be needed if scrapers have difficulty excavating the material directly.

8.3.4 Soil and Aggregate Processing (optional)

On-site soil and aggregate processing can be set up to screen rock and aggregate materials for use in the erosion protection layer, landfill gas-venting layer, and ET apron flow distribution trenches. The on-site soils contain significant cobble and gravel percentages, and appear suitable for processing based on nearby commercial quarrying and processing of similar soils. On-site materials processing is common construction practice and can be effectively set-up for short-term operation. Soils processing is typically a more time consuming process than other aspects of the earthwork project; therefore, timeframes to process the necessary material quantities should be carefully considered in planning the critical timeline for the construction schedule.

8.3.5 Soil Transportation

Transportation of soil from off-site sources must address numerous environmental and public safety issues. The material quantities for this project are significant (Tables 6 and 7), and depending on the volume of off-site materials used, impacts from haul vehicle may be a critical issue. Based on the material quantities, transportation of the main cover construction materials will require many thousands of truckloads of material. Transportation on public highways will require appropriate approvals, which have not been included as part of this conceptual design project.

The haul distance from off-site quarries will have a significant impact on the construction cost, and costs are expected rise dramatically if transportation distances become excessive. Since the soil and rock materials needed for the bulk of construction will require fairly common characteristics, these materials should be available from nearby locations.

Two previous reports, (KH, 1996 and EG&G, 1994), provide additional information on transportation issues. The EG&G report evaluates borrow sources, including transportation over public highways and the locations of many of the commercial quarries operating in the area in 1994. If an off-site borrow location is used, the increase in daily truck traffic on the highways will have to be addressed as a public safety issue. The KH report, a decision document for the Present Landfill, addresses air quality impacts for a planned haul road across the northern part of RFETS leading directly to the LaFarge Quarry. This report identified a 2.5-mile haul road to the LaFarge Quarry as a feasible option for the import of soils.

8.3.6 Soil Placement

The ET cover will be constructed in a manner that limits compaction, which will require the careful selection of placement equipment and establishment of haul routes. This is important for the establishment of vegetation, which requires specified densities to permit optimum root growth and maximize water-holding capacity. Soil compaction will be limited to approximately 80 to 90 percent of Standard Proctor density. Compaction of soils will not be needed as with typical earthwork, and this will provide savings in construction cost and speed progress.

Undoubtedly, excessive compaction of certain portions of the construction site will occur as a result of temporary haul roads and vehicle traffic. As needed, any over-compacted areas will be ripped and loosened as the final soil preparation.

Minimal soil compaction can be achieved by the use of tracked or low-weight wheeled vehicles in combination with the placement of thick lifts of two feet or more. Where weight restrictions are important, such as public roadway crossings, farm-type tractors may be used to haul and place soil using scraper trailers; usually with a set of two or three linked scrapers. The use of low wheel-weight vehicles may be advantageous as it will keep the need for final ripping to a minimum.

The degree to which soil compaction occurs during placement will depend largely on the moisture content of the material. Soils observed at the nearby LaFarge Quarry are relatively moist in the shallow and deep soil profile. Based on these limited observations, RFETS soils appear to be in the range of optimum moisture, which indicates they will tend to compact significantly during routine construction. Specifying and controlling soil moisture during construction can limit the degree of compaction, but only if soil moisture is significantly drier than optimum. Importing drier or processed soils may be an option to meet specifications. As a practical consideration, drying of soils in the quantities needed may be difficult to achieve or control. However, a combination of construction methods to limit soil compaction and final ripping and processing as needed to loosen the soil, will be capable of meeting the soil density specifications.

8.3.7 Gas-Venting Aggregate Layer Placement

The gas-venting aggregate will be clean gravel, free of fines to provide good air-flow permeability. The aggregate will be a processed, screened material either imported from an off-site commercial source or processed on-site. Sieving is adequate, since the presence of some fines will not significantly change air permeability. Placement and spreading of the material will follow standard earthwork practices. The gentle slopes of less than 14 percent will not present any difficulty for constructibility of the aggregate layer.

8.3.8 Piping Installation

Piping installation for the passive landfill gas-venting system will generally follow standard industry practices for installation of landfill gas collection system piping for active landfill extraction systems. The design requirements and construction methods for these systems are well understood from numerous applications across the U.S. Various piping materials and installation methods may be used, but the most common for landfill gas collection applications is welded HDPE pipe. Field fusion of the HDPE pipe should be conducted by qualified personnel and should meet specified QC and testing requirements.

Final design of the piping system may take various approaches with constructibility issues in mind. The most practical construction approach envisioned for the conceptual design is the excavation of shallow trenches (approximately 1 foot by 1 foot) into the prepared subgrade soil below the cover. The piping can be installed within these trenches with underlying and overlying gas-venting aggregate as a bedding material. The remaining gas-venting aggregate layer can then be constructed above the bedded piping network.

8.3.9 Geotextile Separation Fabric Installation

A geotextile separation fabric will be installed above the landfill gas-venting aggregate layer to prevent intrusion of fines from the overlying soil-rooting medium. Use of geotextiles for this type of application is common and is very similar to the standard installation of geotextile separation fabric over the drainage aggregate in a landfill liner system. The geotextile is deployed in rolls and the individual panels are seamed together using portable stitching equipment. A 10-to 12-ounce nonwoven geotextile is commonly employed. Final design requirements will need to consider geotextile thickness and strength requirements based on specific soil properties and potential slope and settlement stresses.

8.3.10 ET Apron Flow Distribution Trenches (optional)

Final design and constructibility issues for flow distribution trenches will need to be addressed if the optional ET apron is implemented. In principle, construction of these trenches will be reasonably practical and simple. Installation of gravel-filled trenches is anticipated to depths of up to 5 to 10 feet. A track-hoe excavator with a bucket width of approximately 2 to 3 feet will most likely be used for trenching.

Trenches may encounter saturated conditions in the vicinity of the seep at the eastern toe of the landfill. The excavation of the ET apron may be near the water table, and trenches may extend into the shallow groundwater. Trenches may need to be stabilized if excessive sloughing of soils occurs. However, it is anticipated that trenches may be excavated relatively easily to the planned depths, including excavation of up to about 5 feet into saturated materials.

Currently, a treatment system is operating at the location of the seep at the eastern toe of the landfill. Construction of the ET cover will extend over this area, and the existing treatment system will need to be removed. The ET apron is one option for elimination of the seep, but other treatment methods may also be selected. Suitable plans will need to be developed to transition from the current treatment system to the new system. The ET cover can provide for this transition because part or all of the ET apron trenches can be constructed while the existing treatment system continues to operate. The existing treatment system can then be shut down to begin to allow passive flow of seepage into the ET apron. Other interim measures to provide dewatering or treatment of the seep can be developed, if necessary.

Trenches will be backfilled with gravel to create permeable conduits to distribute seep water in the shallow soils, where the water is available for uptake by vegetation for enhanced ET. Screened on-site gravel may be suitable for this application. The trenches may be only partially filled with gravel, with placement of a choking layer soil of specified gradation over the gravel to prevent entry of fine-grained soil particles from above. Two to three feet of soil suitable as a rooting medium will be placed in the upper portion of the trench to maintain the continuity of the ET apron vegetation.

8.3.11 Revegetation

Revegetation plans must meet KH Ecology Group requirements, but should also follow fairly standard practices for seed application and mulching. Either drill seeding or hydro-seeding may be used without difficulty on gentle slopes that are readily accessible. Mulching and crimping may be used, as needed, to temporarily stabilize the soil surface until plants germinate and become established.

Soil amendments, if needed to provide added nutrients and organic matter, will be tilled into the soil at specified depths as soil placement occurs. The soil used for the erosion protection layer may be a processed material, with rock and gravel added for erosion resistance. Soil amendments could be added to this topsoil during processing, either by mixing and tilling the soil or other methods.

8.3.12 Construction Methods Summary

Proposed construction methods for the ET cover follow standard industry standards for general earthwork projects. The construction methods are straightforward and uncomplicated, and there are many qualified and competitive contractors capable of performing this work. The only unique element of construction is the requirement for low compaction, which can be readily handled with low ground pressure (lgp) construction equipment and careful haul route planning.

8.4 Project Implementation and Construction Schedule

This section presents a preliminary schedule (Figure 14) for ET cover construction and full implementation of the design and construction project. The schedule includes final engineering design and construction, but does not include the current review and approval process. This is because the approval process is linked to many other issues and decisions in the in the overall context of Present Landfill final closure and site-wide RFETS closure plans.

The schedule assumes the selection of a reasonably close soil borrow site; either on-site or within a short haul distance where soil can be provided to the project at the quantities desired for an efficient construction sequence. To place 5,000 cy of soil per day requires approximately 200 truckloads of soil from an off-site borrow source. This is approximately the quantity of soil that might be excavated on-site with six to eight scrapers, or with one or two excavators and six to eight haul trucks.

WBS	Task Name
1	**Final Engineering Design**
1.1	Geotechnical Investigation and Materials Testing
1.2	Cover Performance Modeling
1.3	Design Calculations/Review and Approval
1.4	Design Drawings/Review and Approval
1.5	Construction Specifications
1.6	Construction Cost Estimate
1.7	Contract Documents/Review and Approval
2	**Bid Administration**
2.1	Solicit Construction Bids/Prequalification
2.2	Contractor Bid Preparation
2.3	Select Contractor
2.4	Negotiate/Sign Contract
3	**Construction**
3.1	Contractor Lead Time
3.2	Site Preparation/Clear and Grub
3.3	ET Apron Excavation (optional)
3.4	Rock and Gravel Processing (optional)
3.5	Subgrade Soil Placement
3.6	ET Apron Gravel Trenches
3.7	Gas-Venting Layer Gravel
3.8	Gas-Venting Piping
3.9	Geotextile Separation Fabric
3.10	Soil Rooting Medium
3.11	Erosion Protection Layer
3.12	Seeding/Revegetation
3.13	Site Clean-Up
4	**Construction Certification**
4.1	Engineer's Certification Report
4.2	As-Built Drawings

- Design that is soundly engineered, constructible, and cost-effective
- Support for RFETS environmental restoration objectives for site closure

These goals are reflected in the design criteria presented in Section 2.

1.2 Site Description

The Present Landfill location is shown on the RFETS Site Map in Figure 1. The Present Landfill consists of a waste disposal area of approximately 21 acres with an additional 9 acres of buttress and pond. A landfill site plan is provided in Figure 2.

1.2.1 History

The Present Landfill was operated as a municipal landfill, receiving waste from Rocky Flats facilities from 1968 through 1998. Waste disposal records indicate that the landfill contains approximately 400,000 cubic yards (cy) of waste. The landfill contains primarily municipal and industrial solid waste, and has received some sludge and hazardous waste.

The Present Landfill currently has an interim soil cover over the entire site. Available records provide no details indicating the thickness of the interim soil cover, which was likely constructed in phases at various times over the life of the facility. Cover slopes range from relatively flat to maximums of approximately 7 percent on the landfill "top deck" or "crown" and approximately 30 percent on the eastern side slope. The cover has been seeded and vegetation is becoming established. Passive landfill gas vents have been installed in the interim cover.

Considerable progress has been made in development of a final closure strategy for the Present Landfill. Much of the previous work is compiled in Phase I IM/IRA Decision Document and Closure Plan for Operable Unit 7, Present Landfill (DOE, 1996). This work addresses not only cover design but also groundwater control, surface water quality, and air quality issues.

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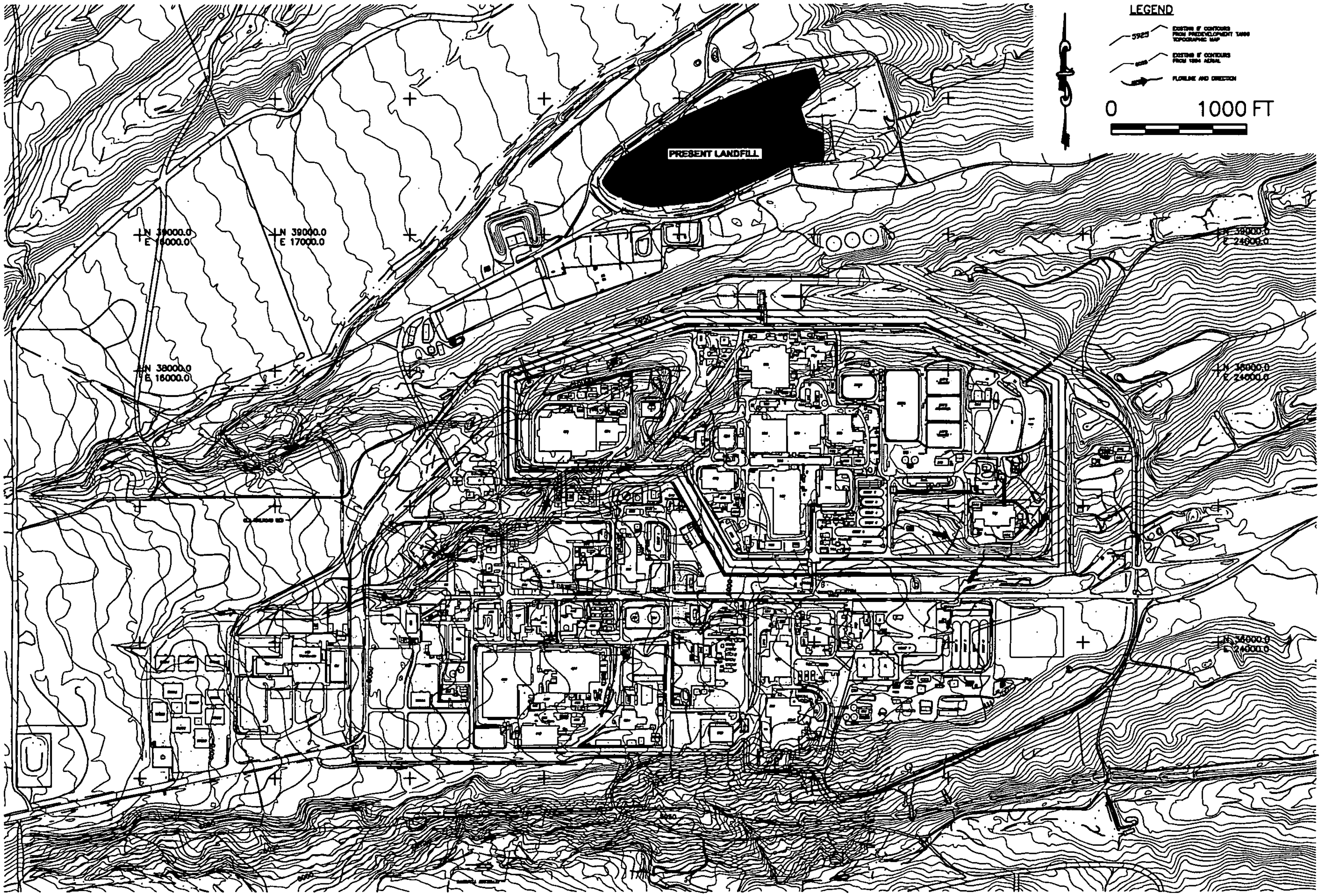

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE
Present Landfill Site Location Map

Figure 1

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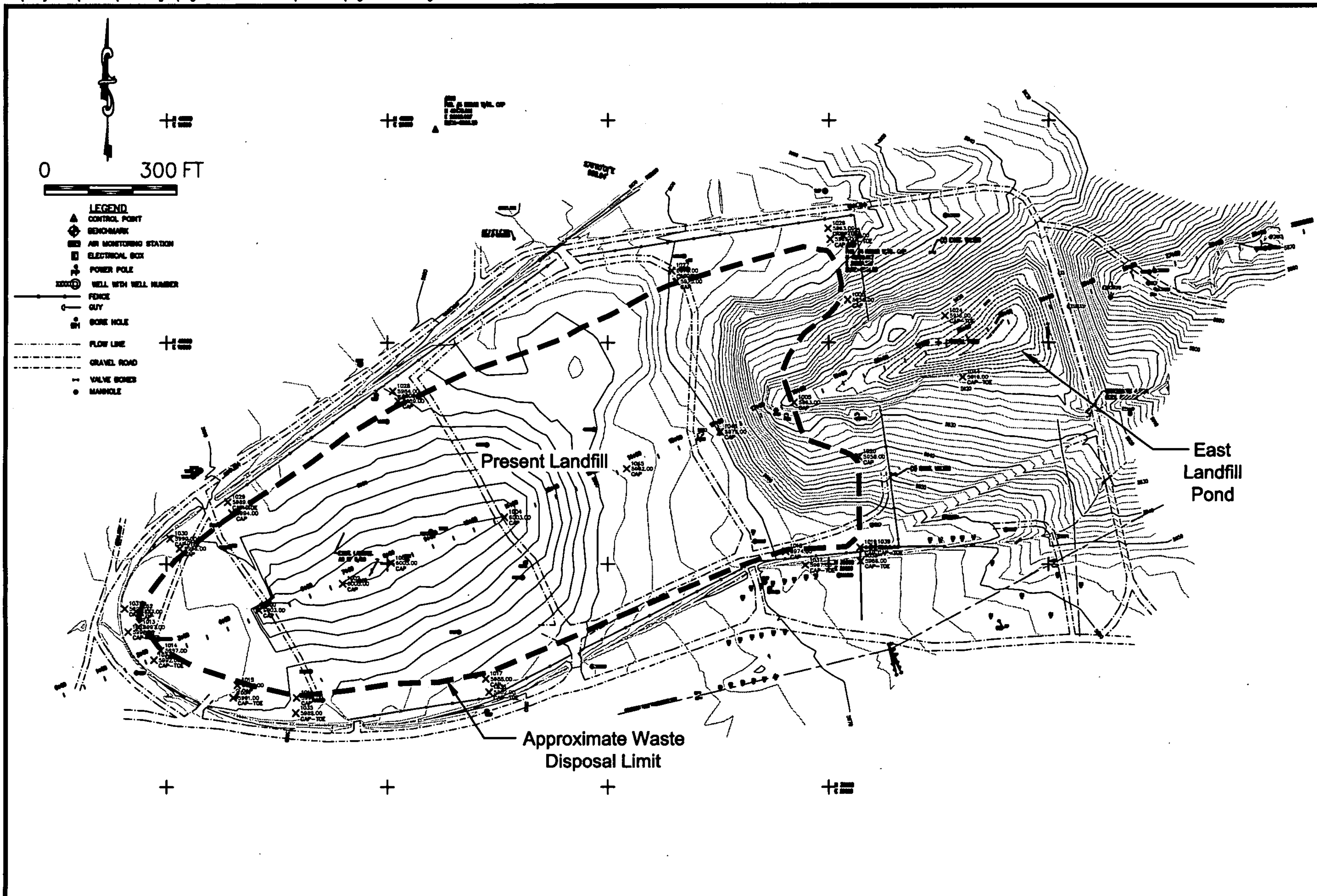

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Present Landfill Site Plan

Figure 2

1.2.2 Regulatory Status

The Present Landfill is a Resource Conservation and Recovery Act (RCRA) Subtitle C interim status unit to be closed under the provisions of Attachment 10 to RFCA. The most significant RFCA compliance issues are related to the quality of shallow groundwater and surface water at the eastern, downgradient end of the landfill. A seep at the toe of the eastern landfill slope discharges an average of about 2-3 gallons per minute through a passive aeration treatment system into the East Landfill Pond (Figure 2). Near the East Landfill Pond, slumping of native soils has occurred due to shallow seeps. To the east of the landfill, No Name Gulch receives inflow from shallow seeps and from storm water diversion channels that route surface water around the landfill. In accordance with RFCA, downgradient and downstream points of compliance need to be established.

2. Design Criteria

Design criteria for the conceptual design process were established as part of the project work plan (DBS&A, 2001b). Design criteria for the Present Landfill were formulated by compiling pertinent regulations, industry standards, and engineering judgments that will ensure proper design of a successful ET cover. The design criteria found in this report are compatible with RFETS project objectives and will serve to enhance closure of the site. Table 1 summarizes the design criteria for the ET cover conceptual design.

The design criteria are the functional requirements used as the basis for the conceptual design. Many of the design criteria are specific requirements while others are objectives that will require further analysis. The design criteria presented in this section include both the minimum requirements that must be achieved by the ET cover conceptual design as well as more stringent requirements that have been identified as requirements to meet RFETS objectives for final closure of the Present Landfill.

2.1 Alternative Cover Performance and Regulatory Compliance

The primary regulatory consideration for ET cover approval is to demonstrate that the cover will meet RFCA Attachment 10 requirements. Conventional cover designs have significant drawbacks in meeting these requirements at the Present Landfill: (1) synthetic flexible membrane liners (FMLs) have an uncertain longevity and may not achieve the desired design life and (2) compacted clay covers desiccate and crack in semi-arid conditions.

ET cover designs have been undergoing technical development and have been gaining more widespread regulatory acceptance in recent years. ET cover applications have included both hazardous waste landfills (RCRA Subtitle C) and municipal landfills (RCRA Subtitle D). For example, Landfills 5 and 6 at Fort Carson, which were approved by CDPHE, were designed to meet Subtitle C requirements (Earth Tech Environment and Infrastructure, Inc., 2000). A number of field studies have provided data substantiating the performance of ET covers, and these long-term studies are ongoing. Many of these projects have been conducted in

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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
Rocky Flats Environmental Technology Site

Subject Area	Design Criteria
Water Balance Modeling Criteria	
Evapotranspiration performance criteria	The ET cover will be designed to be equivalent to a conventional cover design consisting of a flexible membrane liner (FML) and a 2-foot thick clay barrier layer.
Design climatic data/storm event scenarios	Climate input is hourly data from a 48-year precipitation record from Stapleton Airport (Denver, Colorado). Precipitation data for the wettest 1-year, 3-year, and 5-year periods will be input into the model and repeated as necessary to determine long term performance of the covers. Snowmelt will be predicted using the Restricted Degree-Day Radiation Balance Approach using an A_r factor of 0.25.
Vegetation parameters	Average percent of bare soil will be a minimum of 5%. Rooting density functions assume that 80% of root mass occurs in upper 1 foot of cover (AA=0.8705, B1=0.06108, and B2=0.0144). Wilting suction head (HW) is 20,000 cm, root-soil water potential inflection point (HD) is 3,000 cm, anaerobic conditions suction head (HN) is set at 1 cm.
van Genuchten parameters	Alpha = 0.0438, N = 1.37, residual moisture content (θ_r) = 0.11, and saturated moisture content (θ_s) = 0.38.
Cover Soil Properties	
Texture/description [a]	ASTM Soil Classification = clayey sand with gravel. USDA Soil Classification = sandy loam.
Atterberg limits [a]	Liquid limit = 33%, plastic limit 21%, plasticity index = 12%
Particle size distribution [a]	Median particle diameter (d50) = 0.70 mm, uniformity coefficient (cu) = 226 mm, coefficient of curvature (cc) = 8.3 mm, mean particle diameter = 1.9 mm, percent passing No. 4 sieve = 83 percent, percent passing No. 200 sieve = 19 percent.
Density [a]	Dry bulk = 1.63 g/cm^3 (102 pounds per cubic foot [pcf]), wet bulk = 1.76 g/cm^3 (110 pcf)
Calculated porosity [a]	38.6% Volume.
Saturated hydraulic conductivity (K_{sat}) [a]	5.1 x 10^{-4} cm/s.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

ET = Evapotranspiration
USDA = U.S. Department of Agriculture
g/cm^3 = grams per cubic centimeter
cm = centimeters
mm = millimeters
cm/s = centimeters per second
ASTM = American Society for Testing and Materials
NPDES = National Pollutant Discharge Elimination System

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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
Rocky Flats Environmental Technology Site
Page 2 of 3

Subject Area	Design Criteria
Surface Vegetation Provisions	
Type of vegetation	Only native grasses and forbs will be used such as western wheatgrass, green needle grass, native grama and bluestem grasses.
Drought and temperature tolerance	Locally adapted native vegetation can withstand the precipitation and temperature extremes of the area.
Plant rooting	Vegetation shall be able to grow to a depth equaling the full thickness of the ET cover, which will be no less than 3 feet. Root density function parameters: AA=0.8705, B1=0.06108, B2=0.0144.
Ability to thrive in on-site soils	Locally adapted native vegetation can thrive in on-site soils with little maintenance.
Transpiration characteristics	Cool and warm season species will be specified to provide transpiration throughout as much of the year as possible. Locally adapted species of grasses and forbs will transpire all available water in a semiarid climate.
Erosion resistance	Vegetation will assist in limiting cover erosion to less than 2 tons/acre/year.
Erosion Resistance and Storm Water Control	
Storm water parameters and controls	All run-off controls will be designed for a 100-year, 24-hour storm event and implemented in accordance with NPDES standards.
Surface erosional resistance/tolerance	2 tons/acre/year. Allowable erosion must also meet design life criteria.
Minimum and maximum slopes	Minimum = 3%, maximum = 14%.
Run-on controls	All run-on controls will be designed for a 100-year, 24-hour storm event.
Slope Stability	
Slope stability tolerances	Static factor of safety = 1.5, Dynamic factor of safety = 1.3.
Design Life	
Design life period	1,000 years
Subsidence Tolerance and Resistance (Landfill Specific)	
Subsidence criteria	The grading plan will be designed to ensure positive drainage of post-closure settlement grades.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

ET = Evapotranspiration
USDA = U.S. Department of Agriculture
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Table 1. Summary of Technical Design Criteria for Conceptual Design of Present Landfill ET Covers
Rocky Flats Environmental Technology Site

Subject Area	Design Criteria
Landfill Gas and Passive Vent System Criteria (Landfill Specific)	
ET cover landfill gas conditions	The full thickness of the cover will not contain high levels of methane and will possess appropriate levels of oxygen for healthy root growth.
Vent layer	Cobbles, gravel, or approved material meeting approved gradation specifications, with a minimum thickness of 6 inches and a particle diameter no less than 0.5 inch.
Vent well	Vent wells will be constructed of DR-17 high density polyethylene (HDPE) or other suitable materials with a minimum diameter of 2 inches.
Miscellaneous specifications	The vent layer will be designed to provide for the safe collection and venting of landfill gases without danger of explosion. The vent layer should also be able to resist biofouling, prevent infiltration, and withstand settlement.

[a] Soil test results from DBS&A Hydrologic Testing Laboratory

ET = Evapotranspiration
USDA = U.S. Department of Agriculture
g/cm^3 = grams per cubic centimeter
cm = centimeters
mm = millimeters
cm/s = centimeters per second
ASTM = American Society for Testing and Materials
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association with EPA's Alternative Cover Assessment Program (ACAP). Additional details on ACAP are provided in Appendix C.

2.1.1 Alternate Cover Acceptance in the Western U.S.

Alternative cover performance standards and requirements vary greatly across the western U.S. Performance standards from other states with similar semi-arid climates provide some design guidance to evaluate ET cover performance. California standards for equivalence are site-specific and have allowed up to 1 inch per year (inch/yr) percolation. Utah will soon permit a site where equivalent performance allows up to 8 centimeters (3 inches) of percolation. New Mexico defines equivalent covers as those that are within an order of magnitude percolation of the conventional cap at the low percolation values often obtained. (For example, since percolation values for conventional covers are often 0.01 inch/yr or less, New Mexico would define an equivalent cover as one with percolation of 0.1 inch/yr or less.) Arizona sites can meet the equivalence criterion by demonstrating upward flux using numerical models. Nebraska will soon examine existing local ACAP data from Omaha and likely make a decision to approve a nearby alternative cover based upon qualitative evaluation of the data (Appendix C).

2.1.2 Performance Requirements for RFETS ET

The ET cover must be designed to control, minimize, or eliminate, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste decomposition products to the ground or surface waters or to the atmosphere. The cover will be compatible and support all site-wide objectives, regulations, and agreements including all applicable or relevant and appropriate requirements (ARARs). Attachment 10 of RFCA requires that the final cover over the Present Landfill limit infiltration to the extent necessary to prevent continued contaminant impacts that will contribute to the spread or increased concentration of groundwater contaminants.

2.2 Water Balance Modeling Criteria

In addition to meeting RFCA Attachment 10 requirements, ET cover performance was also compared to more standard cover designs. The model selected for this comparison was UNSAT-H (see Appendix D for information about model selection). The comparison demonstrated the ET cover performed similarly to a conventional cover design. Field monitoring during the post-closure care period will be conducted to demonstrate performance. The conceptual design included a water balance modeling effort, which is presented in detail in Appendix A.

2.2.1 Model Input

UNSAT-H uses numerous input parameters, some of which are straightforward (such as site elevation and height of the wind velocity measurements) or have standard values. The more important site-specific parameters such as soil, climatological, and vegetative parameters and/or data inputs are detailed below. Table 2 summarizes the sources of input data for UNSAT-H modeling of the ET cover.

2.2.2 Climatological Parameters

Fairly complete climatological data are available from the Denver Stapleton Airport, where these data have been collected since the late 1940s. Individual precipitation events vary between the airport and RFETS, but long-term trends, variability, and averages are similar. Therefore, climatological data collected from Stapleton Airport were used as input for UNSAT-H modeling of RFETS ET cover. To provide a conservative analysis and account for the somewhat higher precipitation at RFETS, years of high precipitation were selected from Stapleton's climatological record for the modeling analysis.

Climatological data were used that simulated the historic conditions most likely to produce recharge through soil cover. Two time periods for simulation were selected based on an investigation of the 48-year precipitation record at Stapleton Airport. Precipitation during the winter and early spring of 1982 to 1983 was greater than for any similar period of record, and

Table 2. Sources of UNSAT-H Climatological, Vegetation, and Soil Parameters

Input Parameter	Source
Climatological Data	
Precipitation	Denver Airport National Climatic Data Center (NCDC) primary weather station (WBAN #23062)
Temperature	Denver Airport NCDC primary weather station (WBAN #23062)
Dew point	Calculated from temperature and relative humidity, the latter of which was taken from NCDC primary weather station at Denver, Colorado (WBAN #23062)
Solar radiation	Denver Airport NCDC primary weather station (WBAN #23062)
Wind speed	NCDC primary weather station at Denver, Colorado (WBAN #23062)
Cloud cover	NCDC primary weather station at Denver, Colorado (WBAN #23062)
Plant Data	
Leaf area index	Pawnee Grasslands data
Rooting depth	Borrow site observations, soil gas data
Rooting density	Root density function AA=0.8705, B1=0.06108, B2=0.0144 (same parameters as at RMA)
Soil Data	
Cover material hydrologic characteristics	DBS&A laboratory data from LaFarge Quarry sample
Number of layers	Multiple layer systems

WBAN = Weather Bureau, Army, and Navy RMA = Rocky Mountain Arsenal the wettest 1-year, 3-year, and 5-year periods of record are all within the 1965 to 1969 period. Therefore, a 7-year sequence including both of these extreme periods was developed for model input. The series 1982, 1983, 1965, 1966, 1967, 1968, and 1969 were modeled sequentially after first simulating an additional 1982 period to initialize the model. This 7-year period was iterated to determine long-term performance of the cover.

Data from Stapleton Airport will not reflect known differences in wind speed and decrease in solar radiation due to Rocky Flats proximity to the mountains. Both of these factors affect the water balance calculated by UNSAT-H. The stronger winds found at Rocky Flats will increase evaporation and transpiration, while reduced solar radiation in late afternoons will reduce evaporation and transpiration. Both wind speed and solar radiation interact with slope aspect. The decrease in solar radiation due to the mountains will be smaller than differences seen between natural or engineered north and south slopes. The west-facing slopes that may be most affected by reduced evening solar radiation will receive the largest 'benefit' of increased drying from down-canyon winds.

2.2.3 Vegetation Parameters

UNSAT-H requires the input of various parameters for use in predicting the amount of evapotranspiration from the soil profile. One important set of vegetative parameters describes the leaf area index (LAI) distribution throughout the year. Modeling scenarios assumed a standard annual distribution of LAI and did not consider the initial several seasons of reduced LAI while vegetation is being established on the cover. The LAI was based on plant species in the planned RFETS seed mixture.

UNSAT-H linearly interpolates between the specified dates where the LAI is specified by the user. Dates for the last frost in the spring and the first frost in the fall were used, along with other site-specific knowledge related to the growing season at RFETS.

Based on studies conducted at the Rocky Mountain Arsenal (RMA) in Denver, the average percentage of bare soil for cool season and warm season dominated grassland areas are

5 percent and 2 percent, respectively (Morrison Knudsen, 1989). The more conservative value, 5 percent, was used for input to UNSAT-H in the RFETS scenarios.

UNSAT-H requires three parameters to describe the root density function. These parameters were determined by fitting an exponential curve (used by UNSAT-H) to data reported by Liang et al. (1989) for a grassland vegetation on clay/loam soils at the Pawnee Grasslands in northern Colorado. The three parameters are AA=0.8705, B1=0.06108, and B2=0.0144. For perspective, these coefficients cause UNSAT-H to calculate that 80 percent of the root length is in the upper 1 foot of soil. DBS&A requested input from the KH Ecology Group to verify that the root density function was reasonable for use at the RFETS. The specified maximum rooting depth was set equal to the thickness of the cover being modeled. Rooting depths in the borrow material area near the RFETS were observed to reach depths greater than 6 feet, indicating that native vegetation is expected to establish roots through the full thickness of the ET cover soil-rooting medium.

Initially, the suction head corresponding to the water content below which plants wilt and stop transpiring (HW in UNSAT-H) is set at 20,000 centimeters (cm) (almost 20 atmospheres). This value is similar to the in situ values measured in some RMA soil profiles (Fayer, 2000). The suction head corresponding to the water content below which plant transpiration starts to decrease, sometimes referred to as the root-soil-water potential inflection point (HD in UNSAT-H), is set at 3,000 cm based on information presented by Gardner (1983) for loam soils. The suction head corresponding to water content above which plants do not transpire because of anaerobic conditions (HN in UNSAT-H) is set at 1 cm.

2.2.4 Soil Parameters

An investigation was conducted to characterize, sample, and test the typical borrow soil available at RFETS for possible use in constructing the ET cover. Soil was sampled from the LaFarge Quarry adjacent to the northern RFETS boundary, where borrow soil may be obtained during cover construction. The soil is characterized as a sandy loam using the U.S. Department of Agriculture (USDA) Soil Classification and as a clayey sand with gravel using the American Society for Testing and Materials (ASTM) Soil Classification.

Laboratory analysis revealed the following soil characteristics:

- Calculated porosity of the soil is 38.6 percent by volume
- Dry bulk density of the material is 1.63 grams per cubic centimeter (g/cm^3)
- Saturated hydraulic conductivity is 5.1 x 10^{-4} centimeters per second (cm/s)
- van Genuchten parameters for this sample are:
  - $\alpha = 0.0438$
  - N = 1.37
  - residual moisture content (θ_r) = 0.11
  - saturated moisture content (θ_s) = 0.38

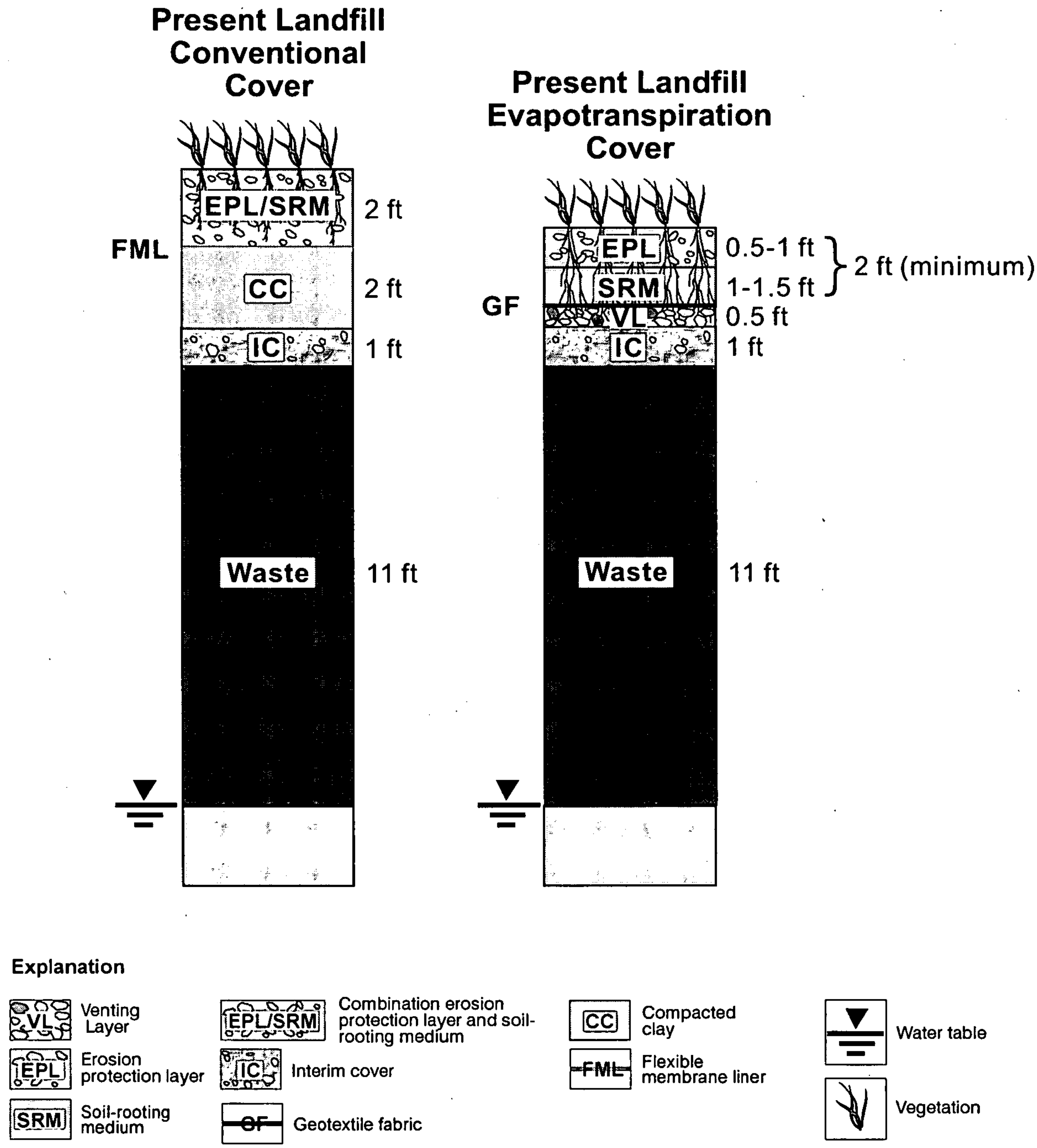
The soil data were input into UNSAT-H, using the van Genuchten function model option (van Genuchten, 1991). An albedo value of 0.2 was used for modeling (Houghton, 1985).

2.2.5 Model Layering

UNSAT-H can simulate systems made up of multiple layers with differing characteristics. The Present Landfill ET cover will be a multilayered system with the major component being a rooting medium soil layer consisting of borrow material with the characteristics described in the section above. Other layers that were characterized for the modeling effort include the erosion protection layer, landfill gas-venting layer, existing interim soil cover, and waste material (Figure 3). Input parameters will be estimated for these layers based on material properties from other sites such as RMA and typical municipal landfills.

2.3 Cover Soil Properties

Cover soil properties must provide sufficient moisture retention capacity to minimize infiltration and support vegetative growth. Critical soil properties include particle size distribution, Atterberg limits, saturated hydraulic conductivity (K_{sat}), texture, and nutrient concentrations. Other material requirements include erosion resistance, cost, and availability. The LaFarge Quarry located adjacent to RFETS has been identified by KH as a potential source of material



ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Modeled Cover Cross-Sections

Figure 3

S:\Projects\9373\Drawings\Figures_4-15-02\Landfill\Figure_3lf.cdr for cover construction. The following data, based on DBS&A test results from the LaFarge Quarry soil, were used during the modeling/design process.

• Texture/Description:	ASTM Soil Classification = clayey sand with gravel USDA Soil Classification = sandy loam
• Atterberg Limits:	Liquid limit = 33 Plastic limit = 21 Plasticity index = 12
• Particle Size Distribution:	Median particle diameter (d_{50}) = 0.70 millimeters (mm) Uniformity coefficient, Cu = 226 Coefficient of curvature, Cc = 8.3 Mean particle diameter = 1.9 mm Percent passing No. 4 sieve (4.75 mm) = 83 percent Percent passing No. 200 sieve (0.075mm) = 19 percent
• Saturated Hydraulic Conductivity (K_{sat}):	5.1×10^{-4} cm/s
• Moisture Content:	Volumetric = 13.1 percent Gravimetric = 8.1 percent
• Density:	Dry bulk = 1.63 g/cm^3 Wet bulk = 1.76 g/cm^3
• Calculated Porosity:	38.6 percent by volume

These soils data are representative of typical borrow soils available for cover construction. Additional soils testing will be needed for the final design once a final borrow source is identified.

2.4 Surface Vegetation Provisions

The current revegetation strategy at RFETS is to restore the native prairie grasslands as closely as possible to pre-existing conditions. Therefore, only native prairie grass and forb seeds will be used for vegetating the ET cover.

The following plant properties are required to ensure healthy, productive, and long-term vegetative growth on the landfill cover:

- *Drought and temperature tolerance:* Locally adapted (native) plants have thrived in the RFETS area for thousands of years under local climatic conditions of temperature and precipitation extremes. These species have developed natural tolerances for local extremes, making them the most suitable choice for the ET cover.

- *Plant rooting:* Roots must establish to a depth of no less than 2 feet. Root density functions for UNSAT-H are specified in Section 2.2.3.

- *Ability to thrive in on-site soils with little or no maintenance:* Long term fertilization and nutrient supplements are not planned at this time; therefore, it is critical that vegetation be able to survive in the conditions of the on-site soil. Native grasses and forbs will be able to thrive with little maintenance. Soil amendments may be provided to supplement borrow material to establish initial vegetation on the cover.

- *Transpiration characteristics:* The ET cover design will use both cool and warm season species to provide transpiration throughout as much of the year as possible. Locally adapted species of grasses and forbs normally transpire all available water in a semi-arid climate such as that of the RFETS.

- *Seed mixture and availability:* The seed mixture will be designed on-site by the KH Ecology Group based on a series of annual vegetation reports, which contain monitoring results from the native plant communities in the Buffer Zone, as well as information on the results of previous revegetation projects at the RFETS. The seed mixture calls for a variety of vegetation rather than a single species for each season. This is important, because if growing conditions become difficult for one species other species may still be able to flourish and ensure continued erosion protection and transpiration. Examples of cool season vegetation include native western wheatgrass, green needle grass, and most forbs; warm season mixtures include native grama and bluestem grasses.

- *Erosion resistance:* Vegetation will assist in limiting cover erosion from both wind and water to less than the 2 tons/acre/year recommended by EPA (1989).

The vegetation implementation schedule will detail appropriate seeding, short-term fertilization, and irrigation times as well as any other significant activities required to ensure a stand of healthy grass on the cover. During cover revegetation, weeds must also be controlled. Irrigation may be used to establish initial vegetation on the cover as necessary.

2.5 Erosion Resistance and Storm Water Control

Surface water runoff at the Present Landfill will be controlled by grading the cover surface to shed water to surrounding areas. To allow for proper drainage of storm water and to prevent ponding and erosion, the following design criteria will be observed.

- Slopes will be designed with a steep enough grade to prevent ponding of storm water, but gentle enough to prevent excessive run-off velocity and optimize long-term erosion control. The minimum slope for the Present Landfill ET cover will be 3 percent. The maximum anticipated slope for the ET cover is 14 percent. Due to existing topography, a slope of less than 14 percent cannot be practicably achieved on the east side of the landfill. Engineered measures will be used to ensure the slope minimizes erosion/abrasion of the cover.

- Soil erosion will not exceed 2 tons/acre/year as recommended by the EPA (EPA, 1989). The Revised Universal Soil Loss Equation (RUSLE) will be used to estimate soil losses over a 1,000-year cover design lifetime.

- Storm water controls, including drainage channels, swales, ponds, etc., will be designed and constructed to hold or control the volume of water expected during a 100-year, 24-hour storm.

- Storm water and erosion controls to prevent soil loss from disturbed areas, excavations, haul roads, borrow areas, and any other areas where erosion develops due to construction activities will be implemented.

- Any necessary run-on control systems will be designed, constructed, operated, and maintained to be capable of preventing flow onto the landfill during peak discharge from a 100-year storm.

2.6 Wetlands Impacts

The cover and storm water control systems will be designed to avoid adverse impacts on existing wetlands. The cover profile will be designed to minimize the footprint of the cover, while also taking into account slope stability and erosion considerations. Wetlands location maps completed at RFETS will be used to determine jurisdictional wetland areas.

The creation of wetlands (possibly as a component of the ET apron) may be considered as a mitigation measure to offset any unavoidable wetlands impacts. The loss of jurisdictional wetlands resulting from cover construction will be mitigated as part of the RFETS site-wide wetlands bank. The wetlands mitigation criteria should be defined, with input from the regulatory agencies, prior to the final design phase.

2.7 Slope Stability

Slopes will be designed to the following specifications:

- Final slopes will not exceed 14 percent to promote stability.
- The minimum factor of safety (FOS) for slopes under static conditions is 1.5.
- The final cover must withstand the maximum horizontal acceleration in earthen materials. The minimum factor of safety for slopes under dynamic (seismic) conditions is 1.3.

2.8 Design Life

Since an ET cover is constructed of unconsolidated soil, it can accommodate differential settlement without damage or loss of integrity. ET covers are suitable to meet the RFETS closure objectives because the longevity of ET covers typically exceeds that of a conventional cover design. This is because an ET cover does not rely on synthetic components that may degrade over time. The longevity of the ET cover will be demonstrated by consideration of natural analogues through a study of soil morphology at the RFETS. Compliance with design life criteria will be based upon the permanence and longevity of natural soil horizons at the RFETS.

The ET cover will be designed with a minimum design life of 1,000 years to meet RFETS closure objectives. The ET cover will be constructed so that there should be no failure of the cover system during its design life as a result of either seismic forces resulting from the maximum credible earthquake or by total erosion based on 1,000-year calculations.

2.9 Constructibility

The ET cover will be designed for standard construction methods. Constructibility issues will be evaluated for all components of the design to ensure the cover can be properly built in an efficient and effective manner.

Construction Quality Assurance (CQA) inspections will be conducted during the construction of the cover to ensure proper construction practices typical of 40 CFR 264.226 and 303. The cover will be inspected periodically for overall uniformity, damage, and imperfections as well as level of compaction (EPA, 1993). The ET cover will be constructed in a manner that will limit compaction to 80 to 90 percent of Standard Proctor density (ASTM D698). This can be achieved by the use of tracked or low-weight wheeled vehicles in combination with the placement of thicker lifts. In the event any portions of the cover are compacted beyond 80 to 90 percent of Standard Proctor density, the area will be ripped to reduce soil density until it meets the specification. The specified soil densities are essential to cover effectiveness to permit optimum root growth and maximize water-holding capacity.

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2.10 Subsidence Tolerance and Resistance

The following design criteria will be observed to ensure the Present Landfill cover will withstand any settlement that occurs over the life of the cover:

- The cover will accommodate settling and subsidence experienced at landfills so that the cover's integrity is maintained.
- Slope design will ensure that total settlement experienced by the cover will provide positive drainage for post-waste settlement grades.
- The cover will be constructed of unconsolidated soil to accommodate differential settlement.
- Maintenance due to settlement will be minimized.
- Positive drainage will be maintained across the final cover.

2.11 Landfill Gas

The cover will be designed and constructed so that landfill gases will not adversely affect the overall performance of the landfill cover and that all components of the cover are compatible with landfill gas, including vegetation. The design must provide for growth of deep-rooted grasses and forbs. Typically, even low methane levels indicate minimal oxygen concentrations. Methane displaces oxygen in the subsurface and reacts with it to form carbon dioxide and water. As required, controls such as passive vents and vent layers will be designed to reduce landfill gas concentrations entering the ET cover.

A landfill gas-venting system will be used to prevent adverse impacts on the rooting depth of vegetation. Such a venting system would consist of a gravel, cobble or approved material (minimum diameter of 0.5 inches) layer with a minimum layer thickness of 6 inches overlain by a geosynthetic fabric layer to prevent soil intrusion. A geosynthetic fabric may be specified due to the short design life requirement of the vent system. Since significant landfill gas production will only occur over the next few decades, it is acceptable if the geosynthetic fabric degrades over time. Passive landfill gas vent wells (minimum diameter of 2 inches) that extend from the gravel layer to the surface would be installed within the gravel layer. The final thickness of the vent layer and the well density will be determined during the design process. The vent layer will be designed to provide for the safe collection and venting of landfill gases. The vent layer should also be able to resist biofouling, prevent infiltration, and withstand settlement.

3. Conceptual Engineering Design

This section presents the ET cover conceptual design, including a description of the cover components and functions, controls for storm water and landfill gas, and means of ensuring slope stability. It also addresses various environmental concerns and the types and quantities of materials needed for cover construction.

Conceptual design drawings, including a site grading plan, cross-sections, and plan details are provided in Figures 4, 5, and 6. Figure 7 shows a three-dimensional view of the planned ET cover for the Present Landfill.

3.1 System Function

The ET cover planned for the Present Landfill must provide required performance in terms of infiltration reduction and erosion protection. ET covers generally consist of a uniform, monolithic soil layer, which achieves infiltration reduction performance through storage of soil moisture until removal of moisture through the natural processes of evaporation and plant transpiration. Establishment of sustainable vegetative communities is promoted, thereby minimizing wind and storm water erosion from the cover surface. The ET cover relies on natural processes to minimize infiltration through the cover, which has been demonstrated throughout the semi-arid western U.S. (Appendix C contains a summary of the current status and application of ET covers).

3.2 System Design Features

3.2.1 Evapotranspiration Modeling

ET cover performance can be modeled to provide a technical basis for the cover design. To model the ET cover, site-specific soil properties must be determined by laboratory testing and local climatic conditions must be considered. The design and performance modeling effort determines the soil thickness needed to provide sufficient capacity for soil moisture storage.

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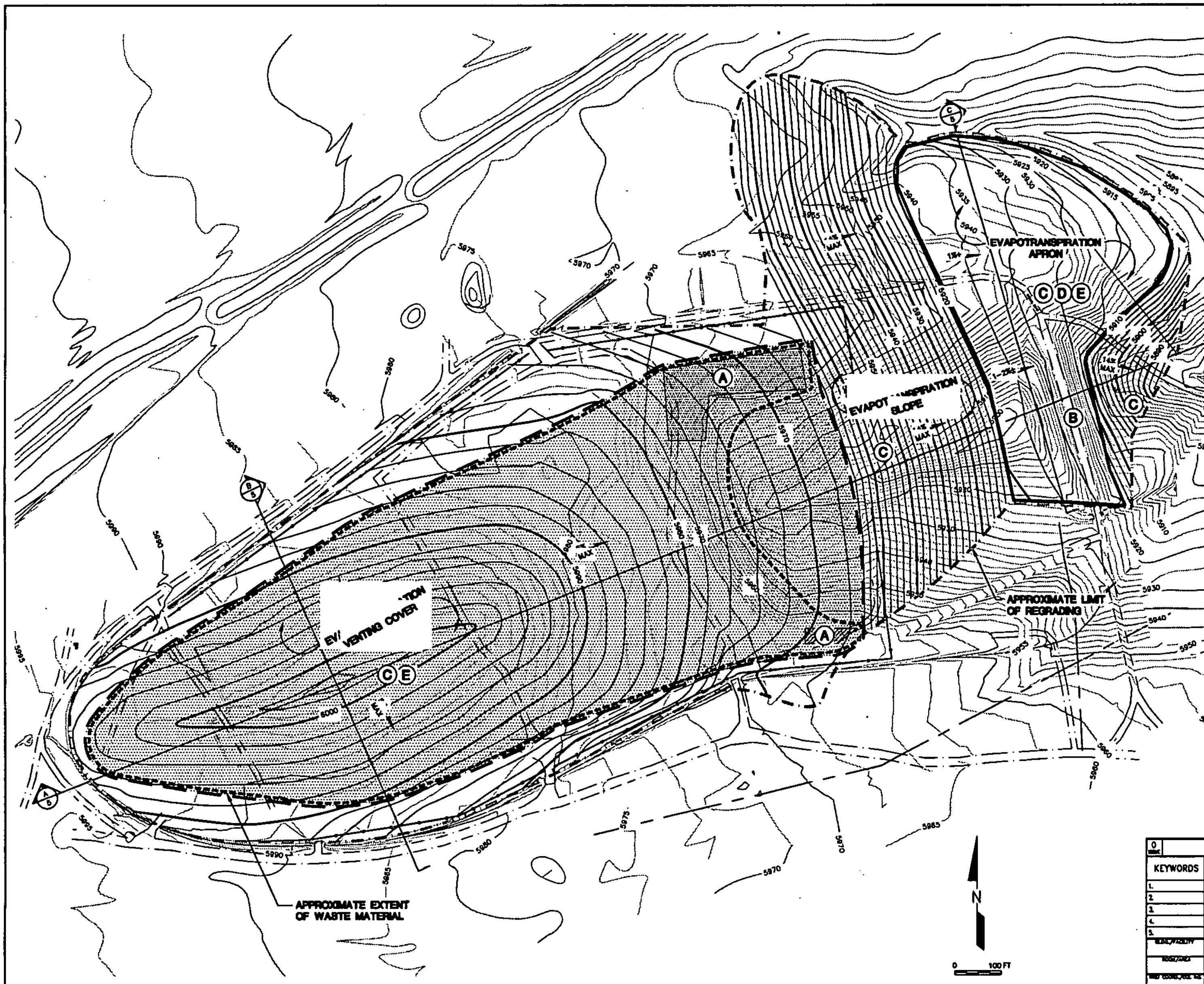


PART	QUAN.	DESCRIPTION	MATERIAL

GENERAL NOTES:

1. THIS DESIGN IS BASED ON TOPOGRAPHIC INFORMATION PROVIDED BY OTHERS. THE ENGINEER CANNOT VALIDATE OR WARRANTY THIS INFORMATION.

DESIGN NOTES:

(A) EXISTING ASBESTOS DISPOSAL AREA.
(B) PORTION OF EXISTING EMBANKMENT TO BE REMOVED
(C) MAXIMUM SLOPE OF COVER SHALL BE 14%. MINIMUM SLOPE SHALL BE 3%.
(D) EVAPOTRANSPIRATION APRON PROVIDES BORROW SOIL SOURCE FOR COVER CONSTRUCTION AT PRESENT LANDFILL.
(E) SEE FIGURE 6 FOR EVAPOTRANSPIRATION COVER DETAILS.

LEGEND:

- 5880 EXISTING GRADE CONTOURS
- 5880 DESIGN GRADE CONTOURS
- APPROXIMATE LIMIT OF REGRADING
- APPROXIMATE EXTENT OF WASTE MATERIAL
- APPROXIMATE LIMIT OF VENTING COVER

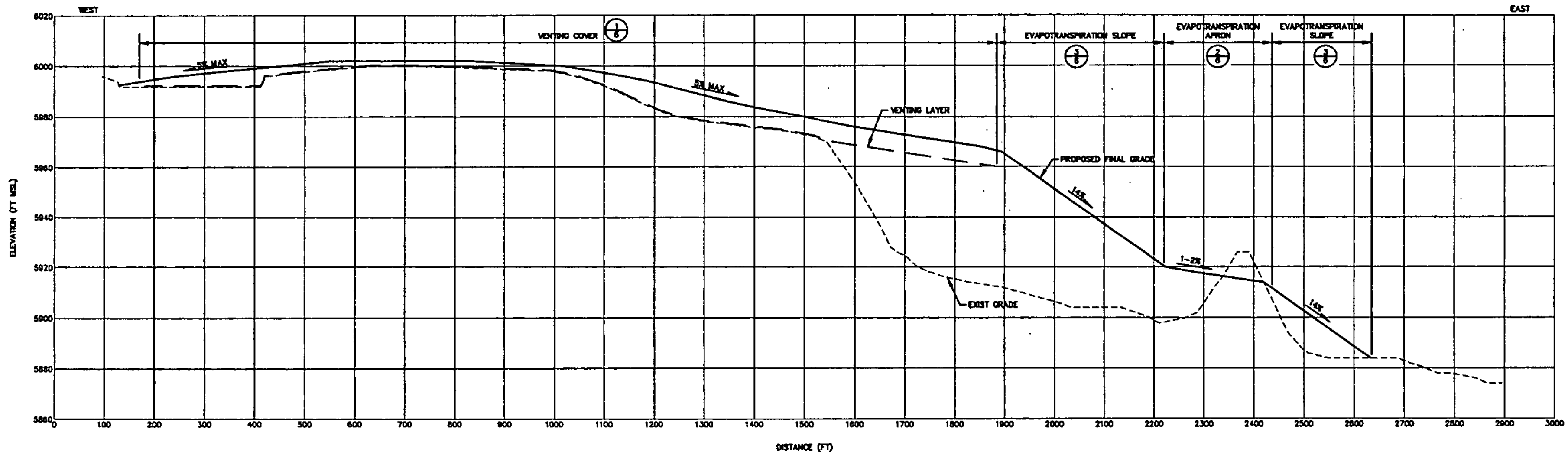
ISSUE	DESCRIPTION			
0	CONCEPTUAL DESIGN			
KEYWORDS	TOLERANCES	DESIGN COMPANY DBS&A		
1.	FRACT. ±	DESIGNED BY ABRAMS	CMA	12/21/01
2.	ANGLE ±	DRAWN BY MAREZ	JAM	12/21/01
3.	DEC. ±	CHECKED BY MILLER	MEM	12/21/01
4.	UNLESS NOTED OTHERWISE	APPROVED BY McGOVERN	MFM	12/21/01
5.	REMOVE BURRS			
BLDG./FACILITY	BREAK EDGES			
ROOM/AREA		CLASSIFIER		
WBS CODE/ROL NO.	SCALE: 1"=100'	UNCLASSIFIED		

PROJECT/WCF NO.

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

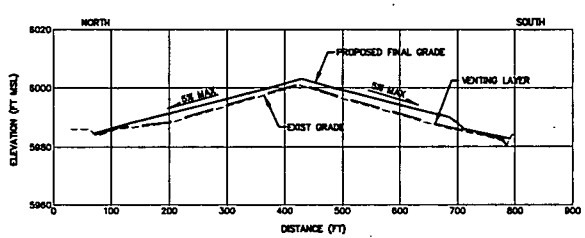
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
PROPOSED GRADING PLAN

SIZE	DRAWING NUMBER	ISSUE
D	FIGURE 4	0



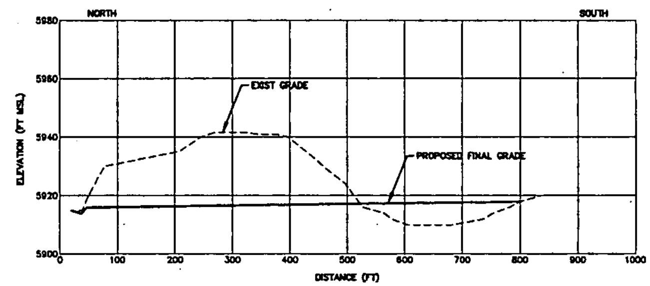
PRESENT LANDFILL SECTION VENTING COVER, SLOPE AND EVAPOTRANSPIRATION APRON (A/4)

HOR: 1"=100'
VERT: 1"=20'



PRESENT LANDFILL SECTION VENTING COVER (B/4)

HOR: 1"=100'
VERT: 1"=20'



PRESENT LANDFILL SECTION EVAPOTRANSPIRATION APRON (C/4)

HOR: 1"=100'
VERT: 1"=20'

0 CONCEPTUAL DESIGN

KEYWORDS

DESIGN COMPANY: DBS&A
DESIGNED BY: ABRAMS CMA 12/21/01
DRAWN BY: MAREZ JAM 12/21/01
CHECKED BY: MILLER MEM 12/21/01
APPROVED BY: McGOVERN MFM 12/21/01

SCALE: AS NOTED

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
TYPICAL CROSS SECTIONS

SIZE: D DRAWING NUMBER: FIGURE 5 ISSUE: 0

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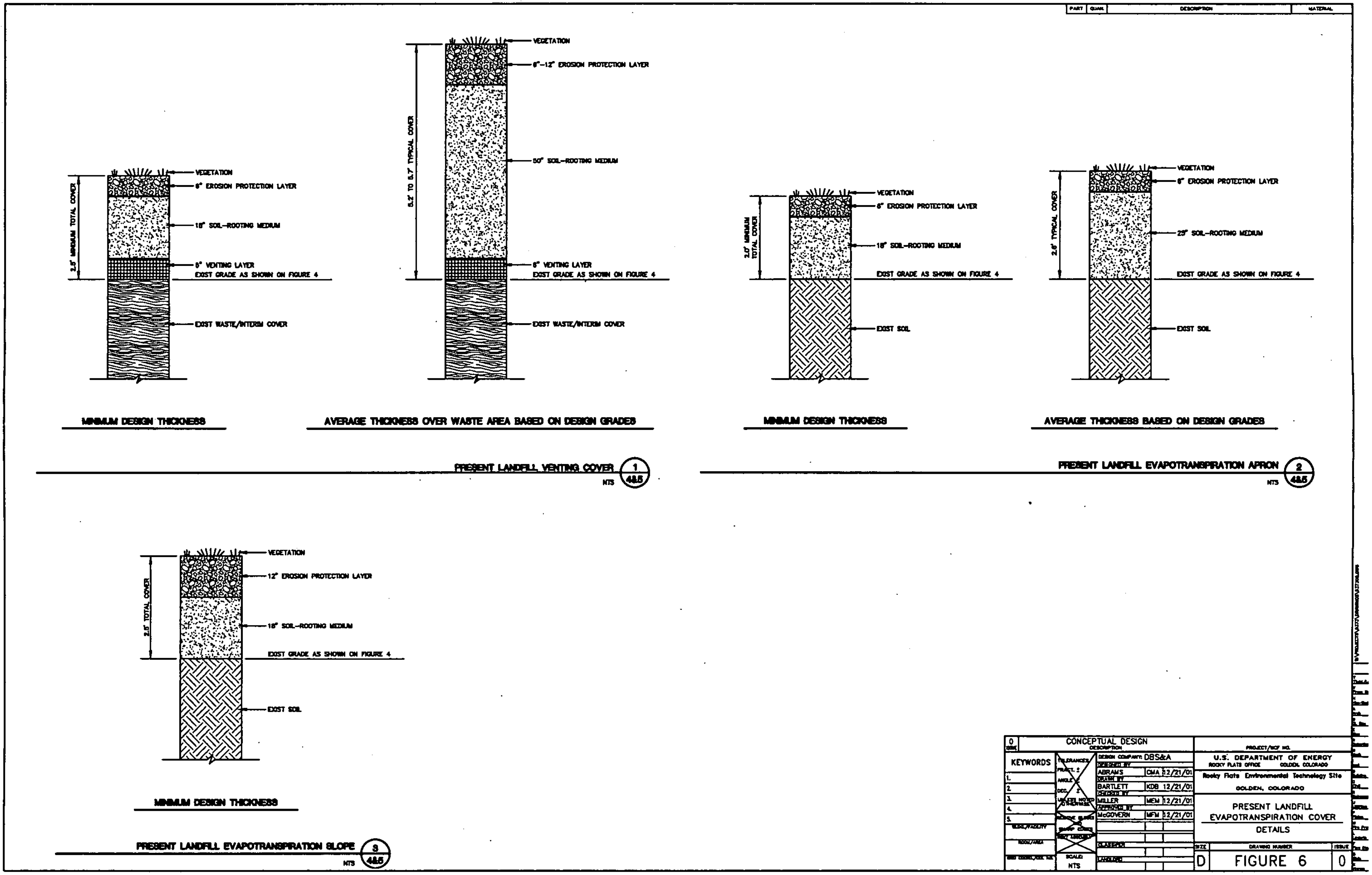

VEGETATION
6" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
6" VENTING LAYER
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST WASTE/INTERIM COVER
2.5' MINIMUM TOTAL COVER
MINIMUM DESIGN THICKNESS
VEGETATION
6"-12" EROSION PROTECTION LAYER
50" SOIL-ROOTING MEDIUM
6" VENTING LAYER
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST WASTE/INTERIM COVER
5.2' TO 5.7' TYPICAL COVER
AVERAGE THICKNESS OVER WASTE AREA BASED ON DESIGN GRADES
PRESENT LANDFILL VENTING COVER
1
4&5
NTS
VEGETATION
6" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.0' MINIMUM TOTAL COVER
MINIMUM DESIGN THICKNESS
VEGETATION
6" EROSION PROTECTION LAYER
23" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.6' TYPICAL COVER
AVERAGE THICKNESS BASED ON DESIGN GRADES
PRESENT LANDFILL EVAPOTRANSPIRATION APRON
2
4&5
NTS
VEGETATION
12" EROSION PROTECTION LAYER
18" SOIL-ROOTING MEDIUM
EXIST GRADE AS SHOWN ON FIGURE 4
EXIST SOIL
2.5' TOTAL COVER
MINIMUM DESIGN THICKNESS
PRESENT LANDFILL EVAPOTRANSPIRATION SLOPE
3
4&5
NTS
PART
QUAN.
DESCRIPTION
MATERIAL
0
CONCEPTUAL DESIGN
DESCRIPTION
KEYWORDS
1.
2.
3.
4.
5.
DESIGN COMPANY: DBS&A
DESIGNED BY
ABRAMS CMA 12/21/01
DRAWN BY
BARTLETT KDB 12/21/01
CHECKED BY
MILLER MEM 12/21/01
APPROVED BY
McGOVERN MFM 12/21/01
SCALE:
NTS
PROJECT/WCF NO.
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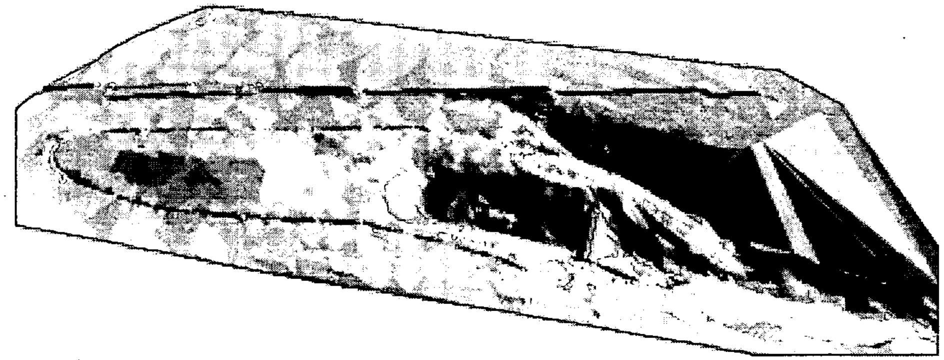
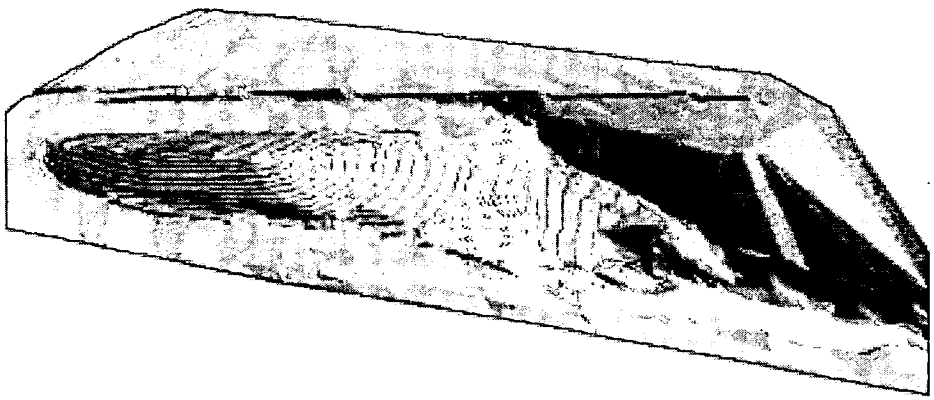
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
DETAILS
SIZE
DRAWING NUMBER
ISSUE
D
FIGURE 6
0

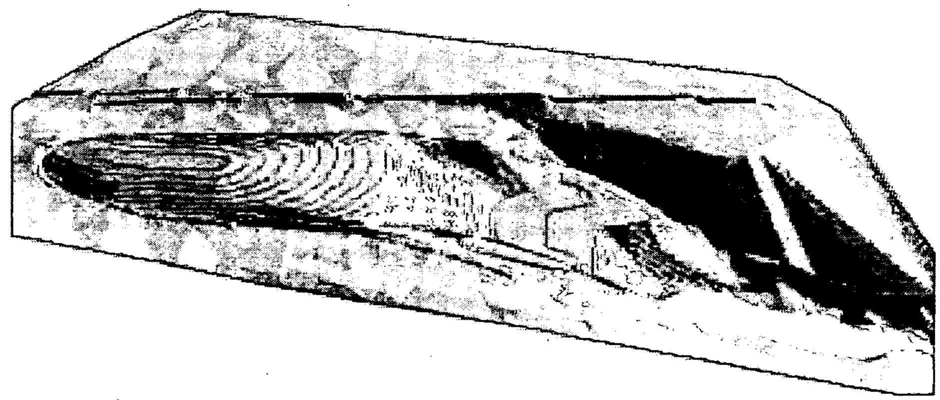
PART	QUAN.	DESCRIPTION	MATERIAL



PRESENT LANDFILL EXISTING GRADE (1 / -) NTS



PRESENT LANDFILL PROPOSED FINAL GRADE (2 / -) NTS



PRESENT LANDFILL PROPOSED FINAL GRADE FOR WASTE RELOCATION OPTION (3 / -) NTS

0	CONCEPTUAL DESIGN		
KEYWORDS	DESIGN COMPANY: DBS&A		
1.	DESIGNED BY ABRAMS	CMA	12/21/01
2.	DRAWN BY BARTLETT	KDB	12/21/01
3.	CHECKED BY MILLER	MEM	12/21/01
4.	APPROVED BY McGOVERN	MFM	12/21/01
5.			
SCALE: NTS			

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PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
3-DIMENSIONAL RENDERINGS

SIZE	DRAWING NUMBER	ISSUE
D	FIGURE 7	0

At RFETS, the critical season for cover design is during winter and spring snowmelts. During this period, when plants are dormant, moisture content increases in the cover soil. The cover soil properties and thickness must provide sufficient soil moisture storage to prevent infiltration below the plant root zone. As plants become active, they remove soil moisture in the root zone and gradually dry the cover soil, thus restoring the capacity for continued soil moisture storage.

3.2.2 System Components

The ET cover for the Present Landfill will be constructed of native materials that will provide long-term performance and compatibility with the overall RFETS environmental restoration objectives for site closure. Most materials used in the ET cover consist of soil and rock with relatively common properties. The ET cover design approach allows for a range of properties that will provide suitable performance, with design optimization possible by adjusting layer thicknesses to account for specific properties of selected materials.

Cover profiles for the Present Landfill are shown in Figure 6. The ET cover includes an erosion protection layer on the surface and an underlying soil-rooting medium layer. At the Present Landfill, a gas-venting layer is included below the soil-rooting medium to allow the passive release of methane and provide a well-oxygenated root zone in the venting layer and overlying soil to promote vegetative growth. Material descriptions for each of the ET cover components are provided in the following sections.

3.2.2.1 Soil-Rooting Medium and Erosion Protection Layers

The primary functional component of the ET cover is the soil-rooting medium. An erosion protection soil layer covering the soil-rooting medium will be used to promote the establishment of vegetation and prevent erosion. These combined soil layers will function together as a thick soil-rooting medium, to store soil moisture and allow vegetation to use and remove the moisture, thereby preventing percolation below this layer. The minimum thickness for the combined soil-rooting medium and erosion protection layers is 24 inches, with an average thickness of approximately 56 to 62 inches, based on the cover layout design grades. The soil-rooting medium is designed to be constructed of soils with a significant fraction of fine-grained silt and clay size particles to ensure suitable moisture retention characteristics.

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The purpose of the erosion protection layer is to minimize both wind and water erosion. In the semi-arid areas of the western U.S. wind causes as much erosion as water. This is particularly true at RFETS because of the unusually strong winds it experiences. The native soils at RFETS are typically clayey soils with cobble and gravel surface armoring, which is naturally resistant to wind erosion. Wind and water erosion can be controlled with an ET cover design that incorporates an erosion protection layer similar to natural surface conditions found at the site.

The erosion protection layer will require a soil suitable for a rooting medium with a significant percentage of gravel and cobbles to inhibit erosive forces of wind and water. The erosion protection layer is designed to use local soil with approximately 25 percent coarse fraction by mass. Material testing should be conducted to develop final material specifications depending on properties of available borrow soils. In cross section, these landfill covers will have a 6-inch minimum to 12-inch maximum thickness, gravel-containing erosion protection layer over several feet of soil cover material. Ultimately, this produces a vegetated surface, partially covered with gravel that is resistant to erosion by wind and water.

The ET cover has been designed with gentle slopes, ranging from 3 to 14 percent, to minimize erosion. Geomorphologic observations at RFETS suggest that natural slopes in this range exhibit long-term stability. The cover design slopes are less steep than naturally occurring, well-vegetated slopes observed in the area.

ET covers can be designed to promote the infiltration of storm water at the surface with soil moisture storage provided by the thick soil-rooting layer. Storm water erosion is minimized through the use of coarse-textured surface soils, while fine-grained soils at depth provide moisture storage capacity. Coarse surface soils can enhance performance through (1) increased surface infiltration of precipitation, (2) increased uniformity of infiltration, and (3) reduced runoff. For example, sands have a high permeability on the order of 10 to 30 centimeters per hour (cm/hr), while sandy clay loams have a lower permeability of around 1 cm/hr. A heavy rainfall has an intensity of about 2 cm/hour, a downpour has an intensity of about 5 cm/hr, and a cloudburst has an intensity of 10 cm/hr. Comparing rainfall intensities to soil hydraulic conductivities shows the effects a fine-textured cover has on components of the cover water balance. A cover that allows water to infiltrate at or near the rate of precipitation will greatly reduce runoff and erosion. The infiltration of water also encourages plant growth and evapotranspiration, providing a cycle of positive feedback to prevent long-term erosion.

3.2.2.2 Gas-Venting Layer

A system of piping and vents will be used at the Present Landfill to provide for passive venting of landfill gas. The purpose of the gas-venting system is to provide a well-oxygenated root zone for vegetation on the ET cover. The gas-venting layer will be constructed below the soil-rooting medium and above the existing interim landfill cover and waste materials. In addition to the primary function of the gas-venting layer to maintain a well-oxygenated root zone for vegetation, the gas-venting layer also has a secondary benefit of minimizing subsurface landfill gas migration and impacts. Subsurface landfill gas can cause explosive risks and impact groundwater quality; however, because the gas-venting layer prevents the build-up of gas pressure, the potential for subsurface landfill gas migration and impacts is reduced.

The landfill gas-venting layer for the Present Landfill will use a coarse aggregate material consisting of gravel-sized particles. The gas-venting layer must be substantially free of fine particles in order to possess good gas permeability characteristics. A network of perforated pipe will be installed within a coarse aggregate layer to vent gas to a series of standpipe gas vents. At the conceptual level, the gas-venting layer is designed to be 6 inches thick to provide sufficient thickness for perforated gas-collection piping to be installed within this layer. The final design may alter this thickness to optimize the combined factors related to venting layer thickness, gas permeability, pipe spacing, vent locations, and landfill gas generation rates. Additional vent and piping design details are provided in section 3.2.4.4.

The gas-venting layer will be the only component of the ET cover design that uses synthetic materials, including piping and geotextiles. Although these synthetic materials have a limited design life, they can be used for the gas-venting layer, because generation of methane from solid waste decomposition occurs over a limited timeframe until the degradable waste materials are fully decomposed. Long-term degradation of the synthetic materials, after the methane-producing period ends, will not compromise the continued performance of the ET cover.

The conceptual design has not examined the quality of landfill gas emissions vented from Present Landfill and whether these emissions comply with emission limits and regulatory permitting or reporting requirements. Landfill gas generation rates have been calculated for the Present Landfill conceptual design, and these calculations show that landfill gas generation rates are expected to continue to decline over time, as waste in the landfill decomposes (Appendix E). A more comprehensive analysis of landfill gas emissions and regulatory compliance will be needed as part of the final design.

3.2.2.3 Vegetation

Selected seed mix will be used to establish vegetation on the ET soil covers at the Present Landfill. Revegetation of the ET cover with native species provides compatibility with the surrounding environment and promotes cover longevity. Considerable information on vegetation has already been assembled by the KH Ecology Group, who will provide final specifications for the seed mix based on the seed available commercially at the time of cover completion. Adjustments may be made to the specified seed mix depending on the construction schedule and the season when seeding occurs.

Soil amendments may be needed to promote the initial establishment of vegetation on the ET cover. The need to add soil amendments will depend on nutrient testing of the selected borrow soil. Additional details on the vegetation plan and possible soil amendments are provided in Section 4.

3.2.2.4 Optional ET Apron

As an option to address containment and treatment of the seep at the eastern toe of the Present Landfill, an extension of the ET cover, or an "ET apron," may be added to the design. The ET apron location and conceptual design configuration is shown in Figure 4. The ET apron will use increased ET to dry up and eliminate water currently discharged at the seep. Elimination of the seep using this approach may be an effective and low-cost solution to achieve compliance with RFCA Attachment 10, which specifies surface water quality requirements. If the seep can be eliminated, compliance is achieved. Water balance modeling needs to be completed during the final design to demonstrate the effectiveness of the ET apron concept.

3.2.2.4.1 Seep Treatment and Control

The ET apron is an attractive approach for control because the system will operate passively. A passive treatment approach will have long-term advantages over other active treatment systems, which might be considered. Whereas many conventional treatment options require long-term operation, maintenance, and monitoring, the ET apron can eliminate these operational issues.

The conceptual design provides an option to construct the ET apron on approximately 6 acres at the eastern end of the Present Landfill. This extension of the Present Landfill ET cover will be recontoured to create a relatively flat (approximately 1 percent slope) treatment area immediately east of the current seep location. The ET apron will be seeded to establish vegetation to increase ET and eliminate the existing seep.

The ET apron will include flow control structures to distribute water flow in the area of the existing landfill seep. The conceptual design envisions a subsurface flow distribution system consisting of French drain type rock and gravel filled trenches to provide pathways for passive flow in the shallow groundwater system. Pipe will not be used in the gravel drains because it has a limited design life. The trenches will provide high transmissivity pathways to distribute water across the surrounding area. Final design of the subsurface flow distribution system in terms of length, depth, and spacing of drains will require considerable site investigation, as described in the geotechnical investigation in Section 6, below. The final design should be coordinated with other RFETS efforts to control groundwater at the Present Landfill.

The size of the ET apron for the conceptual design is based on the acreage needed for vegetation to utilize and remove all of the 2 to 3 gpm flow from the existing seep. This flow rate is equivalent to an annual flow of about 3 acre-feet per year. This seepage flow rate, distributed by subsurface flow across the 6-acre ET apron, provides only about 0.5 acre-foot of water per acre each year. Vegetation can typically utilize approximately 3 acre-feet of water per acre, or more, each year. Therefore, the ET apron is designed to provide enough increased evapotranspiration to eliminate the seep.

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The ET apron will be planted with plant species recommended by the KH Ecology Group. Suitable plant species will differ from vegetation on the main ET cover, since the ET apron will be designed with the seep level and water table in the shallow subsurface. Suitable plant species may include phreatophytes, which establish root systems in the shallow water-bearing zone. The vegetation can be selected by the KH Ecology Group as most appropriate to contribute to site-wide RFETS restoration objectives.

3.2.2.4.2 Soil Borrow Source

Excavation and regrading of soil to construct the 6-acre ET apron may also provide a suitable soil borrow source to supply material for construction of the ET cover over the Present Landfill. A total of approximately 200,000 cy of material will be excavated under the conceptual design grading plan. If used as a borrow source, the ET apron excavation can provide all of the soil needed for construction of the ET cover.

The on-site soil characteristics are suitable to provide material for various components of the ET cover. As needed, soil screening and processing operations may be set up on-site to generate specified soil, gravel, and rock gradations from the on-site material. In this way, additional rock may be added to the erosion protection layer, or clean gravel, free of fines, may be generated for the landfill gas-venting layer. Removal of gravel and rock will also serve to improve the water-holding capacity of the soil-rooting medium, which accounts for the largest quantity of material required.

In addition, the use of on-site soil from the ET apron excavation will be cost-effective. A 1994 borrow source evaluation considered advantages and disadvantages of on-site and off-site borrow sources in detail (EG&G, 1994), and showed that on-site sources would be much less expensive than off-site sources. Transportation costs to import off-site soil were calculated to be more than twice the total cost of on-site soil. A similar cost differential is shown in the construction cost estimate provided in Section 9.

3.2.3 Storm Water Control

The conceptual design approach to storm water control centers on the need to provide for 1,000-year longevity without excessive erosion. To meet the design criterion for longevity, storm water control is achieved by dispersed, overland flow without the use of storm water channels that focus erosive forces. The design will allow storm water to flow off of the ET cover on gentle grades ranging from 3 to 14 percent. This storm water will shed to surrounding native landscape where the water will not come in contact with landfill waste.

The conceptual cover grading plan has been designed to shed storm water in a relatively uniform fashion around the entire cover (Figure 4). Over most of the cover, this is achieved through use of existing grades. At the east end of the landfill, however, waste has been placed on the hill crest to the northwest and southwest of the East Landfill Pond. Rather than focus storm water into a channelized area where erosion control would be difficult to achieve, the conceptual design provides for a wedge of soil to be placed above the East Landfill Pond, filling the valley to a gentle 14 percent grade. This slope is crowned outward to disperse the overland flow.

The conceptual design relies on dispersed overland flow rather than storm water channeling because channels require more long-term maintenance and operation activities.

The ET cover design can support an overland flow approach, because the ET cover will promote infiltration into (but not through) the cover soil and minimize runoff. Infiltration is promoted through the use of highly permeable topsoil and vegetation that reduces downslope flow. The final topsoil design specification should have a permeability on the order of 3 inches per hour (in/hr) (8 cm/hr), to allow infiltration of heavy rainfall.

Overall, the ET cover design will provide runoff characteristics that are similar to undisturbed, native areas at RFETS. Construction of new storm water detention ponds should not be needed to address increased runoff resulting from cover construction. Runoff from the Present Landfill will be addressed within the overall RFETS storm water management system.

3.2.4 Landfill Gas Control

Control of landfill gas is an important design consideration for the ET cover, since the cover's performance depends on well-established vegetation. Methane generated by waste decomposition can affect vegetative growth on landfill covers, by starving plant roots of needed oxygen. Unrestricted root growth throughout the full thickness of the cover is critical to the proper performance of the ET cover. The conceptual ET cover design includes a passive, landfill gas-venting system installed below the soil-rooting medium, to maintain a well-oxygenated root zone to support vegetation. The conceptual design included an evaluation of landfill gas generation rates, which is presented in detail in Appendix E.

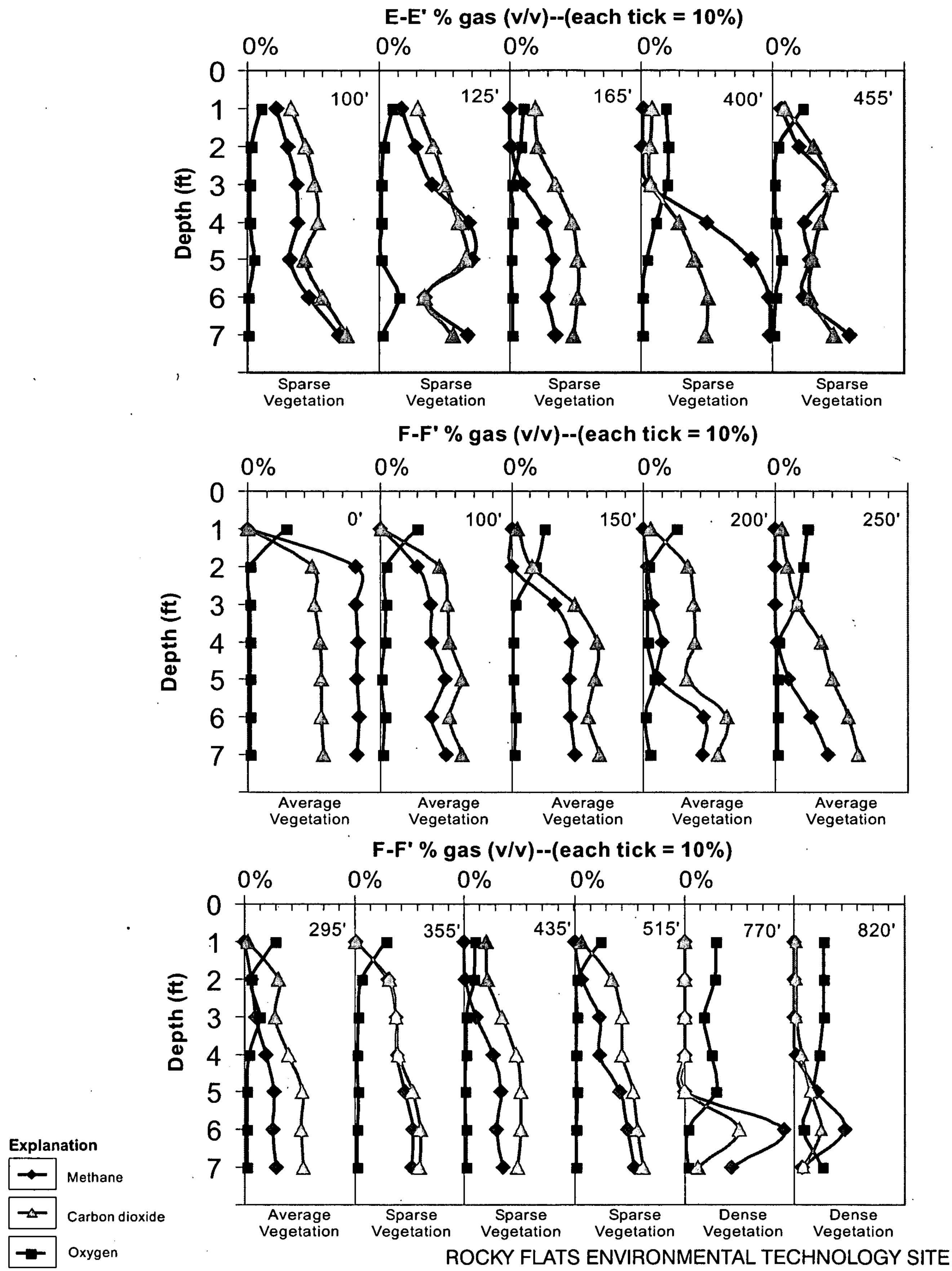
3.2.4.1 Gas Probe Investigation

During September 2001, KH conducted a field investigation to examine landfill gas conditions in the existing, interim, soil cover over the Present Landfill. The investigation used a soil probe to collect gas samples from the interim cover soils and underlying solid waste. The probe was used to collect samples at 1-foot intervals, up to 7 feet below the cover surface. Probing was conducted on transects across the landfill cover, giving a representative distribution of gas measurement.

Results of the gas probe investigation are depicted graphically in Figure 8. The results show that oxygen is depleted and methane is elevated at depths of only 1 to 2 feet below the cover surface. The investigation indicates that gas generation rates in the Present Landfill are causing significantly elevated methane concentrations in the interim cover soils, at levels, which will significantly limit plant root growth. The gas probe investigation provides current information to support design decisions on the necessity of the gas-venting layer.

3.2.4.2 Gas Generation Modeling

Landfill gas is generated within a waste disposal site by the natural decomposition of the organic materials present. Methane (CH_4) and carbon dioxide (CO_2) are the primary constituents of landfill gas, and are produced by microorganisms within the landfill under anaerobic conditions. The Present Landfill contains decomposable waste materials including mainly municipal and industrial solid waste, and some sludges and hazardous waste. The total



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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Soil Gas Profiles

Figure 8

volume of solid waste in the Present Landfill is reported to be approximately 403,600 cy (308,600 cubic meters [m^3]) (ERM, 1994). Along with the methane produced by waste decomposition, landfill gas typically contains trace concentrations of non-methane organic compounds (NMOCs). This NMOC fraction often contains various hazardous air pollutants (HAPs) and volatile organic compounds (VOCs) (EPA, 1998).

Conditions of the waste and landfill are also of vital importance to the generation of landfill gas. Moisture content of the waste is by far the most critical variable in the determination of landfill gas generation rate, controlling the rate of waste decomposition and gas production. Moisture content does not change the total amount of gas that is produced from a given waste quantity, but it determines the rate and duration of gas generation. A methane survey conducted at the Present Landfill found that waste is moist (ERM, 1994), and high moisture conditions are expected to persist due to seepage into the lower portion of the landfill. Therefore, waste decomposition and gas generation is likely to occur in the Present Landfill at near peak rates.

Landfill gas generation rates for the Present Landfill were estimated using EPA's Landfill Gas Emissions Model Version 2.0 (LandGEM). The model shows a peak landfill gas (LFG) generation in 1998, immediately after the closure of the landfill, and LFG generation rates are now declining. The maximum gas generation rates for 1998 were:

- Methane = 31.1 cubic feet per minute (cfm)
- Carbon dioxide = 25.4 cfm
- NMOCs = 0.14 cfm
- Total LFG = 56.7 cfm

Figure 9 is a graphical representation of the LandGEM model output. The modeling results indicate that landfill gas generation is expected to reach very low rates in a timeframe of approximately 25 years. The current methane generation rate of approximately 50 cubic feet per minute (cfm) is expected to decline to less than 20 cfm by 2025, and to less than 3 cfm by 2075. The majority of methane produced by waste decomposition (approximately 80 percent) is calculated to occur by 2025, and nearly all of the gas production is expected to occur by 2075.

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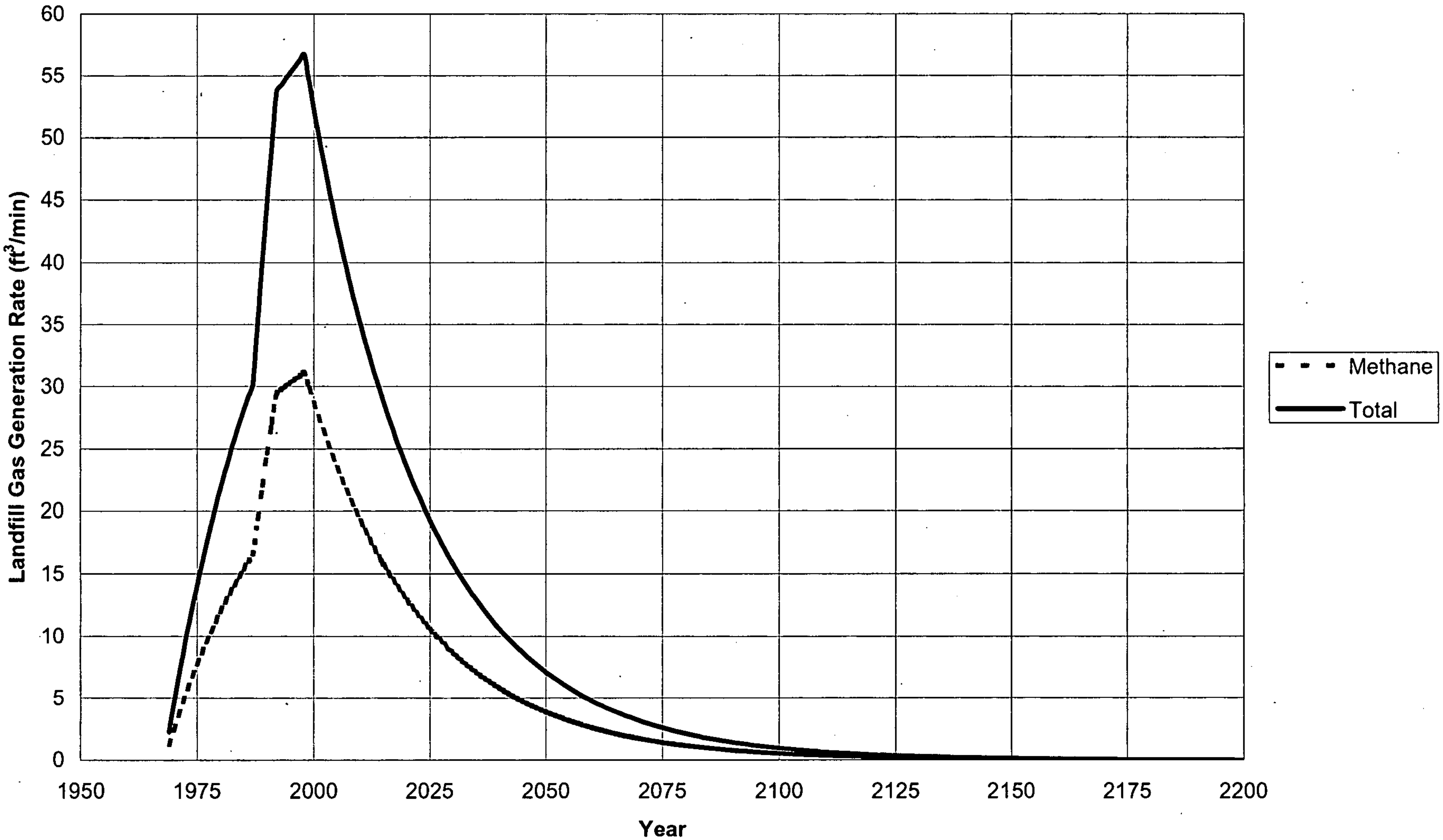


Note: Methane generation rate constant, k=0.04

Figure 9

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Landfill Gas Generation at the Present Landfill

3.2.4.3 *Vent and Piping Design*

The gas-venting layer design is shown schematically in Figure 10. It includes:

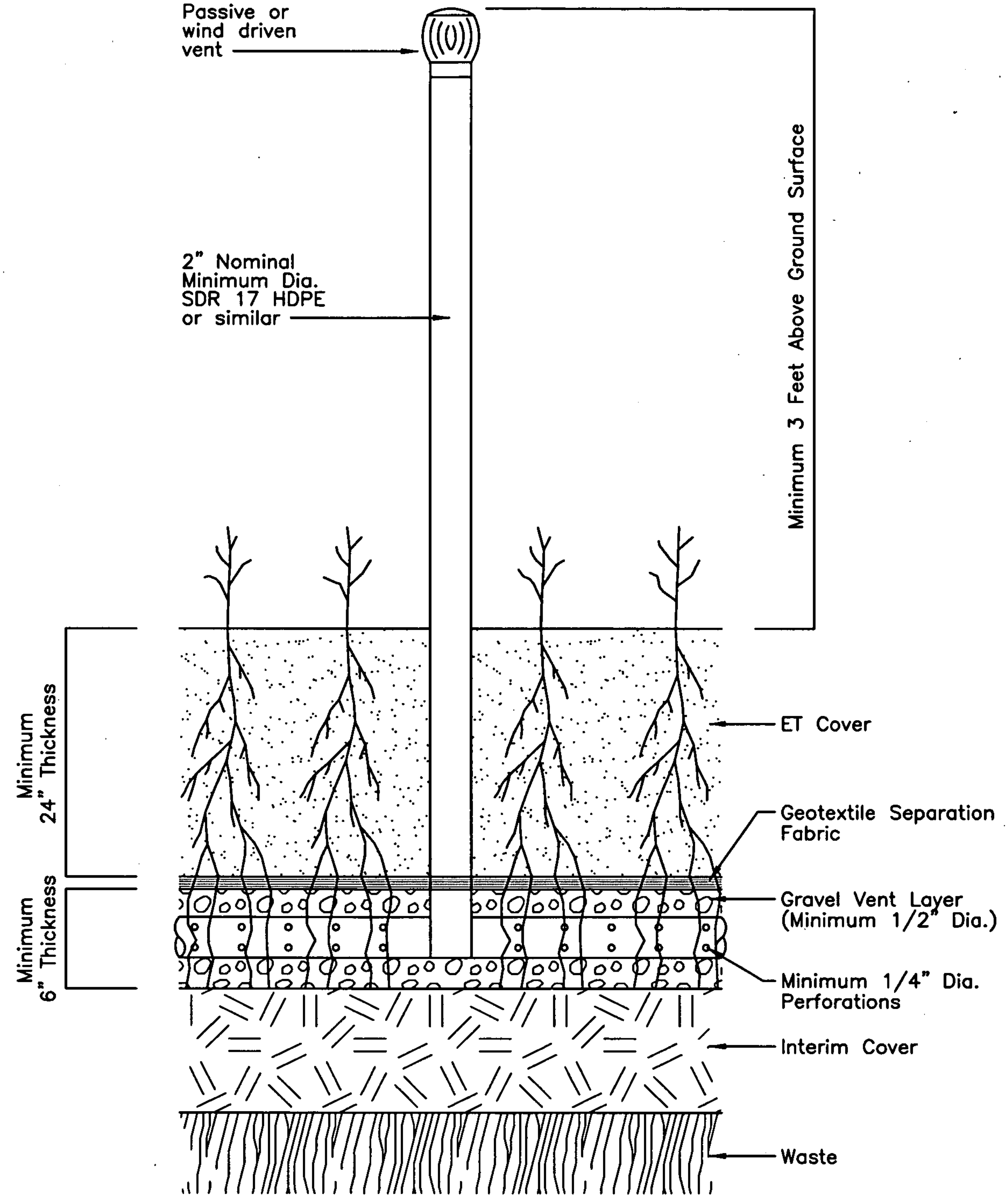
- A network of perforated vent pipes laid horizontally to collect landfill gas.
- A series of vertical vent pipes to allow passive venting of landfill gas to the atmosphere.
- A geotextile filter fabric placed above the gas-venting layer to prevent fine-grained particles from filtering down from the overlying soil-rooting medium into the aggregate.

The piping network will consist of a series of perforated pipes in a grid pattern to provide redundancy and an added factor of safety in design. Vent pipe design must be compatible with final land use plans, particularly if public access to the area is allowed. The network of piping and vents will provide secondary gas pathways should an individual pipe segment become blocked or otherwise fail. A grid of perforated piping at approximate 100-foot spacings should provide adequate gas capture and flow rates to provide a well-oxygenated soil-rooting zone for the ET cover. Final design of the gas-venting system will need to determine the required pipe spacing in conjunction with coarse aggregate gas permeability specifications. The system can also be used with blowers if needed to meet facility performance requirements.

Periodic maintenance of the gas vents will be needed during the operational life of the gas-venting system. When gas generation rates have declined to a level at which the venting system is no longer needed, after approximately 25 to 75 years, the gas vents may be removed. The vent standpipes can be cut off and plugged below grade, with the remainder of the piping network left in place. The holes left by plugging will be replaced with soil of a lower permeability than the rest of the ET cover soil, thereby eliminating any possible preferential pathway for either gas flow or moisture infiltration. The points of cover repair will revegetate naturally and effectively merge with the ET cover vegetation.

3.2.4.4 *Landfill Gas Regulatory Overview*

The installation of an ET cover will not change the regulatory compliance status of the Present Landfill. At this time the landfill does not appear to have any applicable regulatory requirements on air emissions. The ET cover is not expected to increase emissions of any contaminant;



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ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

Conceptual Passive Vent Well and Vent Layer Detail

Figure 10

therefore, the cover will not trigger any emissions based regulatory program. Cover construction permits may be required that pertain to particulate emissions.

The application of air quality regulations to the Present Landfill should be addressed as part of the overall air quality analysis of the RFETS site. The ET cover construction is not expected to increase emissions from the landfill or affect any related regulatory requirements that may already apply to the landfill.

3.2.5 Slope Stability

Slope stability of the proposed ET cover for the Present Landfill was analyzed to ensure that the cover will be stable and remain in place permanently, under both static and dynamic (seismic) conditions. The analysis of slope stability demonstrates compliance with the design criteria presented in Section 2, which requires compliance with the following factors of safety.

- Final slopes will not exceed 14 percent to promote stability. The minimum FOS for slopes under static conditions will be 1.5.

- Demonstrate that the final cover can withstand the maximum horizontal acceleration in earthen materials for the landfill. The minimum factor of safety for slopes under dynamic (seismic) conditions will be 1.3.

The slope stability analysis demonstrates that the ET cover will meet the required factors of safety and the specified slope angles. The maximum design slope for the Present Landfill is 14 percent, which occurs on the east side of the landfill. The ET cover is designed with relatively gentle slopes not only for slope stability both also for erosion resistance.

The design slopes for the ET cover conceptual design are based on the work of other investigators at RFETS, who have analyzed slope stability for similar applications. Slope stability of a final cover for the Original Landfill (OU5) was evaluated in a previous report (DOE, 1995). The Original Landfill exhibits unstable slope conditions in an area of shallow groundwater and seeps, south of the RFETS industrial area. The Original Landfill contains solid

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waste deposited on Rocky Flats Alluvium, which overlies weathered claystone. These geotechnical conditions are similar to the Present Landfill. This 1995 study found that slopes of 14 percent (7:1) are stable for the final cover profile over the saturated geologic materials. Additional, unpublished slope stability analyses for RFETS have shown similar results, with 14 percent slopes (7:1) stable over saturated materials and 18 percent slopes (5.5:1) stable over unsaturated materials (Doty, 2001).

A description of the slope stability analysis and results is provided in the following section.

3.2.5.1 Modeling Approach

Slope stability modeling was performed by using the computer-based program XSTABL, Version 5. XSTABL was developed by Sharma (1995) for the purposes of creating a fully integrated slope analysis program in which the user can develop the slope geometry and perform the analysis all in one single program. The slope analysis portion of XSTABL uses a modified version of the popular STABL program, originally developed by Purdue University. XSTABL was chosen to perform the slope stability analysis for RFETS due to its simplicity of use, accuracy, and overall reputation as an excellent tool for performing slope stability analyses for these types of projects.

The first step in modeling the slope stability was to enter a simplified geometry of the steepest slope at the Present Landfill into XSTABL. An assumption is made that if the steepest slope meets the specified factors of safety, then all other slopes will meet the requirements as well. As described above the steepest slope at the landfill site is the east slope at a design grade of 14 percent. The geometry was entered into the model by plugging coordinate data from the cross-sections into the model.

The next slope stability modeling step was to assign soil properties to each of the soil units (layers) that comprise the cover. Model input parameters were conservative with regard to predicting possible slope failure mechanisms. The soil properties required by XSTABL are wet bulk density, angle of internal friction, and cohesion. Since test data were not available for all of these parameters, conservative assumptions and typical values were used to perform the analysis. Table 3 summarizes soil properties for the ET cover and the Present Landfill as used in the model.

Table 3. Slope Stability Material Properties for ET Cover and Present Landfill

Soil Layer	Soil Unit No. (as assigned in the model)	Wet Bulk Density (pcf)	Angle of Internal Friction (degrees)	Cohesion (psf)
Erosion protection layer	1	118.6	30	0.5
Soil-rooting medium	1	118.6	30	0.5
Landfill gas-venting layer	3	96.3	30	0.0
Intermediate cover	1	118.6	30	0.5
Solid waste	2	33.0	10	0.0
Native soil beneath waste	1	118.6	30	0.5

pcf = Pounds per cubic foot psf = Pounds per square foot

The final step in modeling was to run a circular failure analysis using Bishop's Method of Slices on the slope geometry using the soil properties shown in Table 3. Static analysis was performed initially, then a coefficient of horizontal acceleration was entered into the model for dynamic analysis. The value used for horizontal acceleration was attained from the U.S. Geological Survey (USGS) National Seismic Hazard Mapping Project. A coefficient of 0.112 g or 11.2 percent of gravitational acceleration was used in XSTABL for the RFETS slope analysis. This value corresponds to the Golden, Colorado area and indicates with a 2 percent probability of an earthquake of the above intensity in the next 50-year period. This equates to a 10 percent probability of a 0.112 g earthquake in the next 250 years, or a 40 percent probability within the next 1,000 years. Over the 1,000-year design life of the ET cover, a significant probability exists for a seismic event of this intensity; therefore, the cover design must provide a sufficient factor of safety to demonstrate stability under dynamic conditions. Additional analyses were completed to show slope stability for larger potential earthquakes with a ground acceleration up to 0.25 g. This is the earthquake cited by DOE (1995) as having a scaled return probability of 1,000 to 10,000 years.

3.2.5.2 Modeling Results

The XSTABL analysis results were favorable, showing the ET cover to be stable under all conditions modeled. Results from XSTABL are presented in terms of factor of safety. In theory, any factor of safety of 1.0 or higher means the slope will not fail. But because the process of modeling usually simplifies a situation the factors of safety are set to higher standards than 1.0 to allow for additional tolerance. As stated above, the required factors of safety set for RFETS are 1.5 under static conditions and 1.3 under dynamic conditions. XSTABL generated the ten most critical surfaces for the slope of concern and therefore output the ten lowest factors of safety. Table 4 summarizes slope stability results for the Present Landfill.

Table 4. Slope Stability Analysis Results for the Present Landfill

Area Analyzed	Type of Analysis	Minimum Factor of Safety
East cover slope at 14% grade	Static	4.766
East cover slope at 14% grade	Dynamic	2.458
East cover slope at 14% above existing waste slope at 31% grade	Static	13.793
East cover slope at 14% above existing waste slope at 31% grade	Dynamic	3.220

The Present Landfill was analyzed in two distinct critical areas. The first point of analysis was the steepest slope at the Present Landfill, which is the 14 percent east slope. Under both static and dynamic conditions the factors of safety are well above the specified values of 1.5 (static) and 1.3 (dynamic) for this slope. The second point of analysis was the portion of the east slope of the landfill that overlies the east edge of waste that is at an existing grade of approximately 31 percent. Since this waste is graded at such a steep angle it was a critical area to analyze to ensure the slope containing the waste would remain structurally sound once the cover was constructed over the waste slope. XSTABL results for this area generated factors of safety several times the design criteria. This indicates that the waste, the east slope, and the entire landfill will remain in place even during a probable seismic event.

The slope stability analyses completed for the conceptual design show that the gentle ET cover slopes are conservative with regard to slope stability. At the final design stage, more detailed slope stability analyses will be needed that include testing of on-site geologic materials and materials planned for cover construction. A complete evaluation is needed of geotechnical conditions present, including possible saturated foundation conditions within the formations supporting the cover. These slope stability analyses should be coordinated with studies currently underway at RFETS to evaluate shallow groundwater conditions and control.

3.2.5.3 Waste Settlement

Solid waste in landfills undergoes long-term settlement, which affects the landfill final cover. This settlement causes gradual changes in the cover slopes and can potentially cause damage to landfill covers. The degree of waste settlement expected at the Present Landfill was analyzed to verify suitable design of the ET cover grading plan (Figure 4). Most importantly, settlement must remain within tolerable limits to provide for continued positive drainage, to prevent ponding on the cover, over the full settlement expected for the 1,000-year design life of the ET cover.

Multiple mechanisms control the rate and degree of waste settlement. Sharma and Lewis (1994) summarize the primary settlement mechanisms as follows:

- Mechanical rotation or reorientation of material
- Raveling (repositioning of particles into smaller voids)
- Physical-chemical changes (corrosion and oxidation)
- Biochemical decomposition (decay, fermentation, anaerobic processes, and aerobic processes)

Waste settles under its own mass and additionally under the placement of external loads such as daily soil cover, additional waste, and final cover. Depending on factors such as waste composition, initial compaction, and environmental conditions, waste typically settles from 5 to 30 percent of its original thickness under its own weight (Edil et al., 1990). This primary waste settlement will occur within approximately the first 5 years of placement. Secondary settlement or compression, due to decomposition and creep processes, will decrease with time, but will continue following closure of the landfill. New wastes have not been placed in the Present Landfill for four years; therefore, most primary settlement has already occurred. Most remaining settlement at the Present Landfill will be caused by settlement due to long-term waste decomposition.

The degree of long-term waste settlement was estimated by four of the most widely accepted methods: the Sowers Method, the modified Sowers Method, the Gibson and Lo Model, and the Power Creep Law. These methods were used to evaluate waste settlement for 5, 10, 30, 50 and 1,000-year periods. The final step of the settlement analysis was to apply the elevation changes estimated by the models to the cross-section of the landfill surface and evaluate the resulting change in grade.

Settlement calculation results are summarized in Table 5. The four models provide relatively consistent results, and over each time-step, the models predict additional settlement of approximately 3 percent, yielding an almost consistent 3 percent increase in settlement during the lifetime of the landfill. During early analysis time-steps, the Sowers and Modified Sowers Methods estimate the largest settlement values. Ultimately, the Gibson and Lo Model predicts the greatest degree of settlement, which is shown in the 1,000-year settlement values for this method.

The change in elevation resulting from waste settlement calculated by each method for the 1,000-year analysis was applied to the design surface of the ET cover. Over the cover cross-sections (as shown in Figure 5) the change in cover elevation was analyzed by lowering the surface elevation at each data point analyzed. This resulted in a modified cover surface geometry that reflects the expected final grade after 1,000 years of waste settlement. Total waste settlement amounts to as much as 6 feet in the areas with the greatest waste thickness. The changes in final grade were found to be within tolerable limits, to continue to provide positive drainage from the ET cover. The minimum 3 to 5 percent slopes designed for the top-deck of the landfill cover will provide positive drainage for the 1,000-year design life of the ET cover.

Table 5. Settlement Calculation Summary

Present Landfill Point Location	Sowers Method		Modified Sowers Method		Powers Creep Law		Gibson and Lo Model	
	30 yr	1,000 yr	30 yr	1,000 yr	30 yr	1,000 yr	30 yr	1,000 yr
East-West Cross-Section Settlement (feet)								
A-200	0.29	0.59	0.19	0.39	0.03	0.10	0.12	0.80
A-400	0.60	1.23	0.40	0.81	0.15	0.53	0.31	2.83
A-600	1.09	2.22	0.72	1.47	0.10	0.36	0.47	3.01
A-800	1.23	2.50	0.81	1.65	0.11	0.41	0.53	3.37
A-1000	1.32	2.68	0.87	1.77	0.12	0.44	0.57	3.62
A-1200	1.14	2.31	0.75	1.53	0.34	1.26	0.54	5.63
A-1400	1.07	2.18	0.71	1.44	0.29	1.07	0.53	5.19
A-1600	0.69	1.41	0.46	0.93	0.46	1.69	0.16	2.81
A-1800	0.22	0.45	0.15	0.30	0.30	1.11	0.01	0.30
North-South Cross-Section Settlement (feet)								
B-100	0.63	1.27	0.41	0.84	0.06	0.21	0.27	1.72
B-300	0.83	1.68	0.55	1.11	0.08	0.27	0.36	2.27
B-400	0.94	1.91	0.62	1.26	0.09	0.31	0.40	2.58
B-500	0.92	1.86	0.61	1.23	0.08	0.30	0.39	2.52
B-700	0.85	1.72	0.56	1.14	0.08	0.28	0.37	2.33

Along with providing positive drainage, the ET cover is also resistant to possible damage caused by differential settlement. Differential settlement can cause shearing in covers with traditional design using compacted clay and/or synthetic liner materials. Because the ET cover is constructed of non-cohesive soil, the Present Landfill cover is resistant to possible damage. The soil cover can undergo slow deformation, without being subject to cracking or other damage. This characteristic of ET covers allows these soil covers to outlast traditional landfill cover designs.

3.2.6 Site Preparation

Prior to construction of the ET cover, site preparation work to remove existing infrastructure will be needed. At the Present Landfill, site preparation will need to address:

- Existing gas vents
- East Landfill Pond and dam
- Existing surface water and groundwater control structures
- Clearing and grubbing

Each of these site preparation items is discussed in detail in the following sections.

3.2.6.1 Existing Gas Vents

A series of gas vents were installed in the interim landfill cover in 1997. The existing vents consist of vertical standpipes installed through the cover and into the underlying waste to allow passive venting of landfill gas. These existing vents will need to be removed prior to construction of the ET cover. Removal of the vents can be easily completed, either by pulling the casing or by plugging the casing with bentonite or grout. If the casing is left in place, it should be cut off below ground surface. The existing gas vents will not be needed following installation of the ET cover gas-venting system.

3.2.6.2 East Landfill Pond and Dam

The East Landfill Pond and dam will need to be removed, prior to cover construction, due to the proximity of the pond to the steep, eastern slope of the Present Landfill. The pond is located approximately 100 feet from the eastern toe of the slope, and a wetlands begins adjacent to the toe of the landfill slope and extends to the dam crest, approximately 600 feet to the east. The seep emerges from the landfill within the wetlands. In order to meet design requirements limiting the final cover slope, the landfill cover must extend beyond the existing landfill slope and will infringe on the pond and wetlands.

The East Landfill Pond was constructed in 1974 as a catchment to prevent discharge of the seep to surface water in No Name Gulch. Although eliminating the pond will reduce wetland habitat, it appears that maintaining the pond is not compatible with overall closure requirements for the Present Landfill. Two fundamental issues are apparent:

- *Flow Reduction*: The existing seep, which flows to the pond, will have a reduced flow as a result of the ET cover reducing infiltration into the landfill and additional groundwater controls being investigated at RFETS to reduce groundwater inflow to the landfill. The reduced seep flow will affect the pond level. An overall water balance for the pond, considering inflows from the seep, groundwater, and surface water, has not been determined.

- *Sedimentation*: Long-term sedimentation will gradually lead to infilling of the shallow, East Landfill Pond. Any additional surface water discharge routed into the pond to make up for the reduced seep inflow, will bring an associated sediment load. Preservation of the pond appears incompatible with the 1,000-year longevity for landfill closure.

Removal of the East Landfill Pond and dam will require that the water in the pond be appropriately discharged.

The conceptual design grading plan calls for removal of the upper portion of the dam and infilling of the pond to construct the ET apron. This earthwork will be completed during cover construction, at the same time a thick wedge of soil is placed over the existing east slope of the landfill. The ET apron, located over the same area as the current pond and dam, will provide similar wetland type habitat as an offset for removal of the pond and surrounding wetland.

3.2.6.3 Existing Surface Water and Groundwater Control Structures

Existing surface water and groundwater control structures route water around the Present Landfill, and discharge the water at multiple points east of the landfill. The effectiveness of these control structures is being examined by others, and the results of this evaluation will determine whether the structures need to be maintained and if additional engineering controls are needed to reduce seepage inflows to the landfill.

The ET cover will overlie portions of the groundwater control structures at the eastern end of the landfill. Final design of the ET cover must be coordinated with the evaluation and design of groundwater control systems to provide compatibility between the two efforts.

The existing surface water diversion ditch around the landfill perimeter should be filled and eliminated during the ET cover earthwork. As described in Section 3.2.3, surface water runoff from the ET cover will be minimized through vegetation and permeable surface soil, and the minor runoff will be discharged by dispersed overland flow. Eliminating the surface water ditch will also reduce infiltration at the landfill perimeter, which may contribute to groundwater inflow into the landfill waste. Filling the ditch will be a minor additional earthwork activity during cover construction.

3.2.6.4 Clearing and Grubbing

All areas where the cover will be placed and areas of excavation for soil borrow will be cleared and grubbed prior to starting earthwork. Existing vegetation should be stripped to provide consistent adhesion between the existing soils and the overlying soil materials placed for cover construction. This is particularly important on the eastern slope of the Present Landfill, where steep slopes of approximately 30 percent currently exist. Clearing and grubbing this slope will avoid creating a potential slippage plane along a layer of matted vegetation. Likewise, vegetation should be stripped from the surface of soil borrow areas to provide consistent borrow soil and avoid irregular amounts of plant material mixed with the borrow soil.

A suitable means of disposal will need to be determined for the vegetation and soil generated by clearing and grubbing. The possibility of contaminants in the material may need to be considered and could affect disposal alternatives. At the Present Landfill, where organic solid wastes have been disposed, it appears suitable to place and compact the clearing and grubbing spoils on a portion of the landfill where additional fill may be useful to reach final design grades. The spoils will exhibit properties much like the rest of the solid waste mass in the landfill and will not affect the ET cover.

3.2.7 Asbestos Disposal Areas

Two asbestos disposal areas are located at the eastern end of the Present Landfill, on slopes above the East Landfill Pond (Figure 4). The location of the asbestos disposal areas presents design challenges regarding the configuration of final cover grades, while meeting slope grading limitations for slope stability and erosion resistance. To maintain the maximum slope of 14 percent, a thick wedge of soil fill must be placed on the east landfill slope, filling the valley between the north and south asbestos disposal areas.

A second option for consideration is relocating the asbestos into the main landfill disposal cell. Relocating the asbestos allows for significant reduction of the eastern extent of the ET cover and using a much smaller quantity of soil required for cover construction. Asbestos is typically handled in this type of operation by thoroughly wetting the material prior to excavation using a front-end loader, and placement into a haul truck with a plastic liner to cover and seal-in the material. The asbestos can then be disposed of in narrow trenches and immediately covered with soil. Relocating the asbestos disposal cells will require careful handling of the material and compliance with all air quality requirements and worker safety requirements.

3.2.7.1 Design Options

The Present Landfill ET cover conceptual design configuration includes two different design options:

- *Primary Option*: Cover asbestos in-place. The conceptual ET cover configuration for this option is shown in Figure 4.

- *Secondary Option*: Relocate asbestos into main disposal cell. The conceptual ET cover configuration for this option is shown in Figure 11. Cover cross-sections and details for the waste relocation option are shown in Figures 12 and 13.

Selecting between the two conceptual design options is not straightforward at this point. This is in part due to an absence of information regarding the nature and quantity of asbestos disposed and the exact location and depths of asbestos disposal cells. Some of the advantages and disadvantages of the two options are described in the following sections.

3.2.7.2 Cover Asbestos In Place

Leaving the asbestos in its current disposal locations and covering it in place has the primary advantage of minimizing potential risks of exposing and potentially releasing contaminants. Administrative efforts to conduct the asbestos relocation are avoided and the overall project schedule to complete final closure may be expedited. Also, regulatory approvals to complete the asbestos relocation are avoided and public concern will not be raised as a result of waste excavation.

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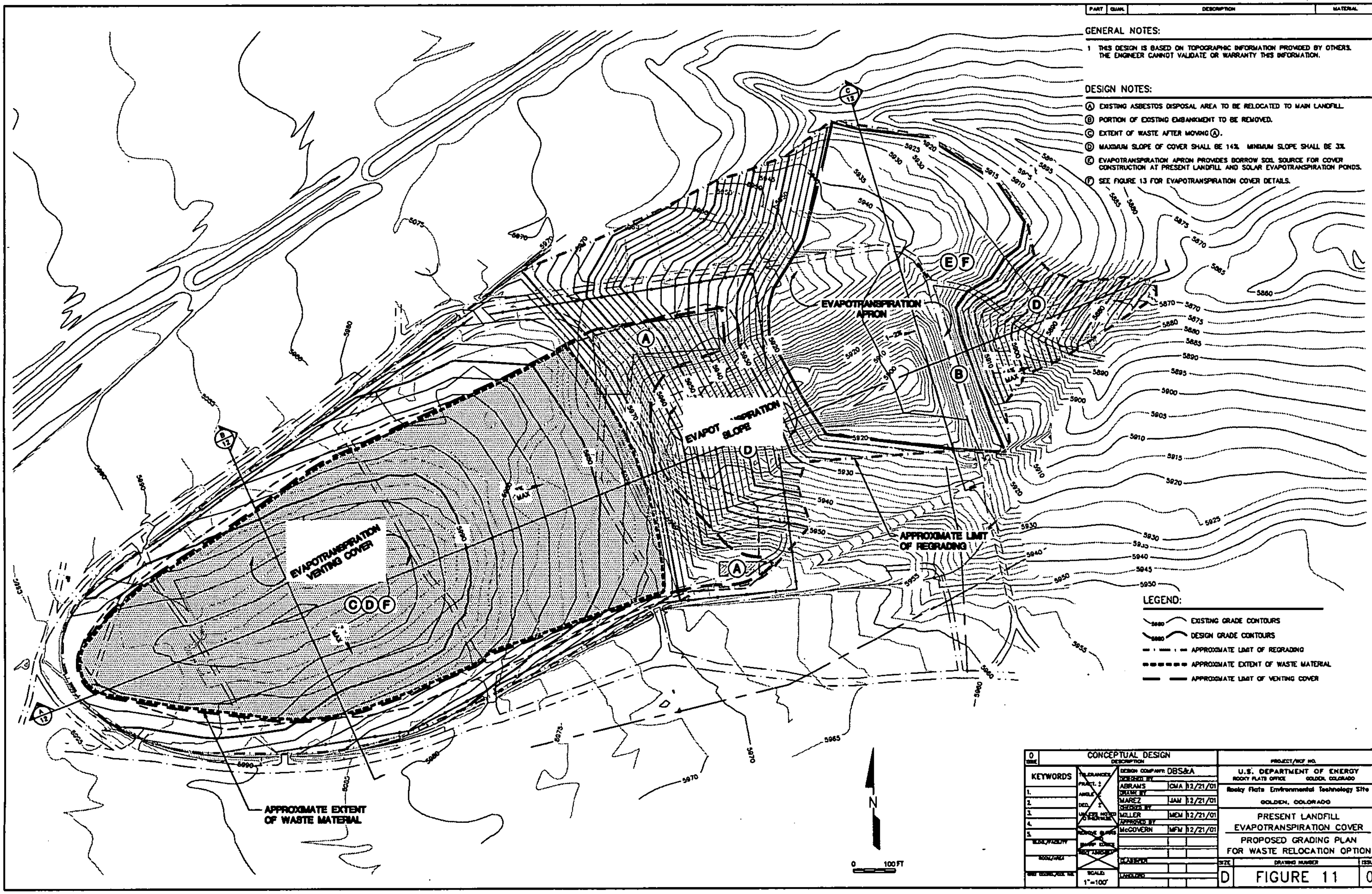
GENERAL NOTES:
1 THIS DESIGN IS BASED ON TOPOGRAPHIC INFORMATION PROVIDED BY OTHERS. THE ENGINEER CANNOT VALIDATE OR WARRANTY THIS INFORMATION.
DESIGN NOTES:
(A) EXISTING ASBESTOS DISPOSAL AREA TO BE RELOCATED TO MAIN LANDFILL.
(B) PORTION OF EXISTING EMBANKMENT TO BE REMOVED.
(C) EXTENT OF WASTE AFTER MOVING (A).
(D) MAXIMUM SLOPE OF COVER SHALL BE 14% MINIMUM SLOPE SHALL BE 3%
(E) EVAPOTRANSPIRATION APRON PROVIDES BORROW SOIL SOURCE FOR COVER CONSTRUCTION AT PRESENT LANDFILL AND SOLAR EVAPOTRANSPIRATION PONDS.
(F) SEE FIGURE 13 FOR EVAPOTRANSPIRATION COVER DETAILS.
EVAPOTRANSPIRATION APRON
EVAPOTRANSPIRATION SLOPE
EVAPOTRANSPIRATION VENTING COVER
APPROXIMATE LIMIT OF REGRADING
APPROXIMATE EXTENT OF WASTE MATERIAL
LEGEND:
EXISTING GRADE CONTOURS
DESIGN GRADE CONTOURS
APPROXIMATE LIMIT OF REGRADING
APPROXIMATE EXTENT OF WASTE MATERIAL
APPROXIMATE LIMIT OF VENTING COVER
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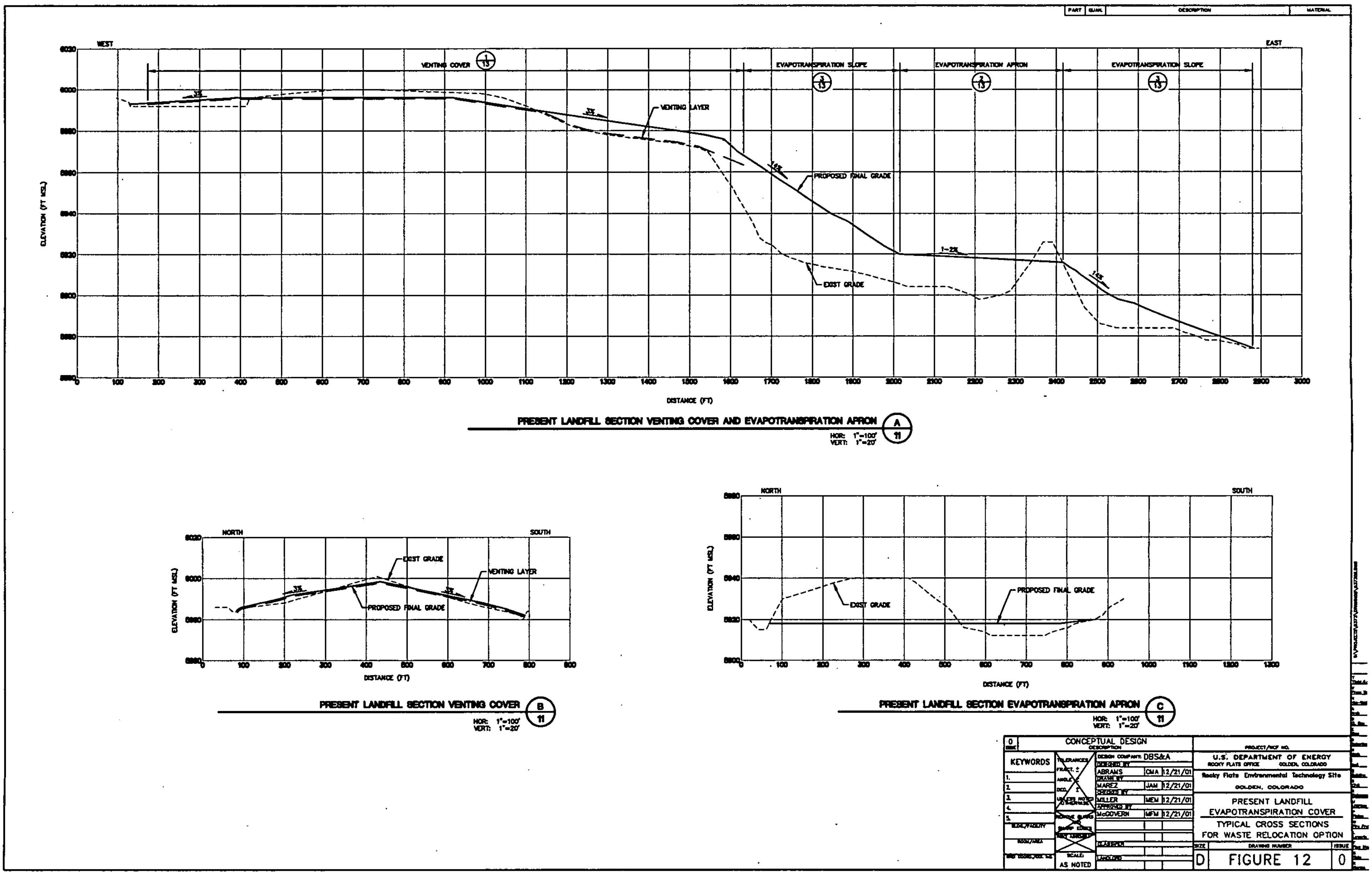
0 100 FT
CONCEPTUAL DESIGN
KEYWORDS
DESIGN COMPANY: DBS&A
ABRAMS CMA 12/21/01
MAREZ JAM 12/21/01
MILLER MEM 12/21/01
McGOVERN MFM 12/21/01
SCALE: 1"=100'
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
PROPOSED GRADING PLAN
FOR WASTE RELOCATION OPTION
D FIGURE 11 0


WEST
EAST
VENTING COVER
EVAPOTRANSPIRATION SLOPE
EVAPOTRANSPIRATION APRON
EVAPOTRANSPIRATION SLOPE
VENTING LAYER
PROPOSED FINAL GRADE
EXIST GRADE
ELEVATION (FT MSL)
DISTANCE (FT)
PRESENT LANDFILL SECTION VENTING COVER AND EVAPOTRANSPIRATION APRON
HOR: 1"=100'
VERT: 1"=20'
NORTH
SOUTH
PRESENT LANDFILL SECTION VENTING COVER
PRESENT LANDFILL SECTION EVAPOTRANSPIRATION APRON
CONCEPTUAL DESIGN
KEYWORDS
DESIGN COMPANY: DBS&A
ABRAMS CMA 12/21/01
MAREZ JAM 12/21/01
MILLER MEM 12/21/01
McGOVERN MFM 12/21/01
SCALE: AS NOTED
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO
PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
TYPICAL CROSS SECTIONS
FOR WASTE RELOCATION OPTION
D
FIGURE 12
0

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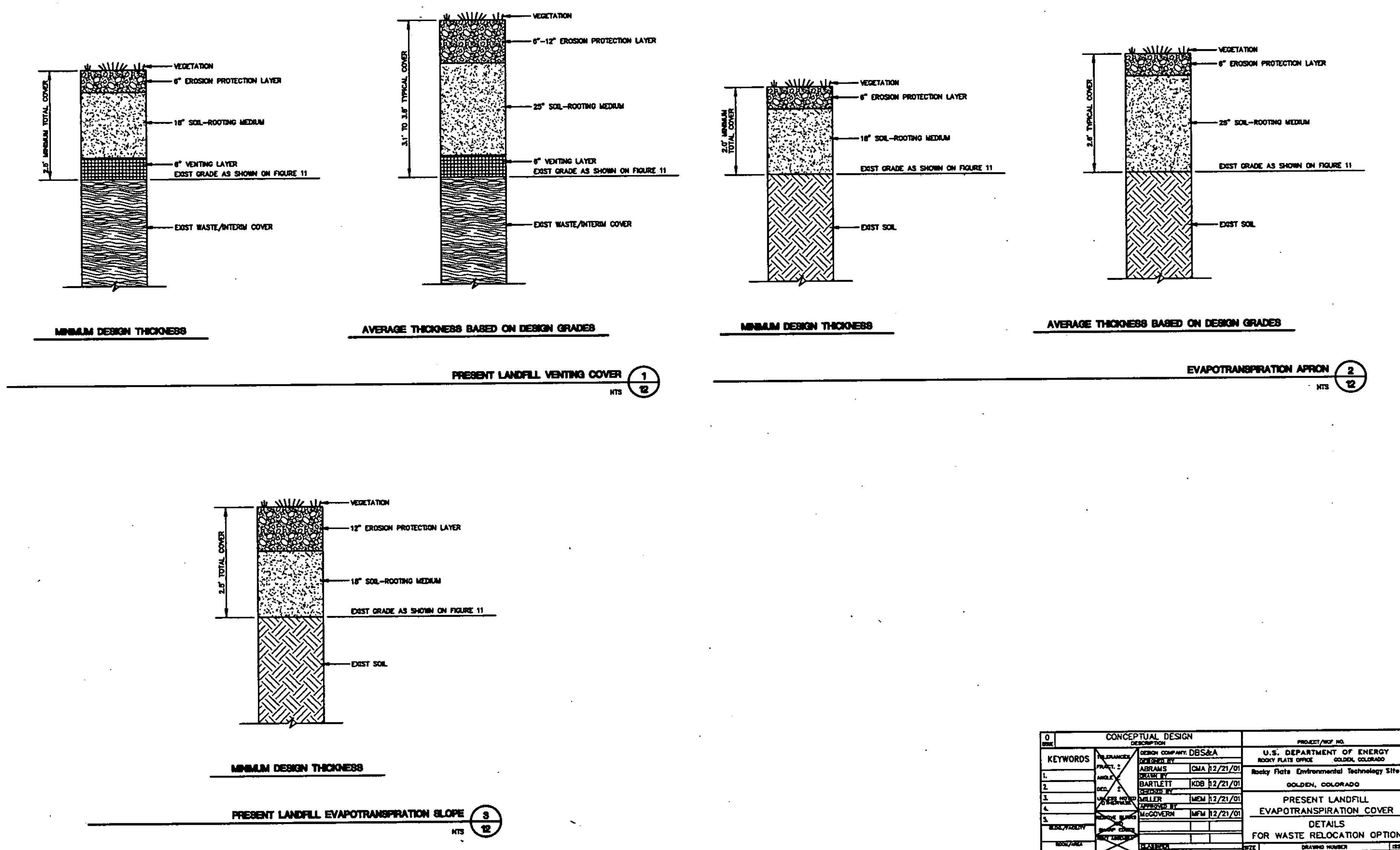
174



PART	QUAN.	DESCRIPTION	MATERIAL

0 CONCEPTUAL DESIGN

DESIGN COMPANY: DBS&A

ABRAMS	CMA	12/21/01
BARTLETT	KDB	12/21/01
MILLER	MEM	12/21/01
McGOVERN	MFM	12/21/01

KEYWORDS

SCALE: NTS

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS OFFICE GOLDEN, COLORADO
Rocky Flats Environmental Technology Site
GOLDEN, COLORADO

PRESENT LANDFILL
EVAPOTRANSPIRATION COVER
DETAILS
FOR WASTE RELOCATION OPTION

SIZE	DRAWING NUMBER	ISSUE
D	FIGURE 13	0

The primary disadvantage of covering the asbestos in-place is that significantly more cover soil is needed to complete the ET cover. The cover acreage is increased and the average cover thickness is substantially increased due to the wedge of soil needed over the east slope of the landfill, between the two asbestos disposal areas. The cover is over 50 feet thick in this wedge, as shown in cross-section A-A' in Figure 5. The soil quantities needed for cover construction to cover the asbestos in place are described in Section 3.4.

3.2.7.3 Relocate Asbestos

Relocating the asbestos into the main Present Landfill disposal cell, has the primary advantage of minimizing the area of the ET cover and substantially reducing the amount of soil required to complete cover construction. As discussed in Section 3.2.2.5, with relocation of the asbestos, a soil balance can be achieved for use of on-site soils regraded from the ET apron excavation area. Without relocation of the asbestos, a large quantity of soil must be imported from off-site, potentially raising additional transportation concerns. The soil quantities needed for cover construction with relocation of the asbestos are described in Section 3.4.

The primary disadvantage of relocating the asbestos is the potential impact on the project schedule that may result from the regulatory review process to complete the asbestos relocation. This issue has not been examined in detail as part of the ET cover conceptual design.

3.2.7.4 Decision-Making for Asbestos Options

The options for the asbestos disposal areas have been identified in the conceptual design effort as a key element of the project, which will require additional consideration for final decision-making. The asbestos options are discussed more fully in Section 3.4.1 on soil balance, and Section 9 on cost estimates. At this time, both options appear to be reasonable alternatives, therefore the conceptual ET cover design includes cover design configurations for both options.

3.3 Material Descriptions and Sources

A variety of soil and rock materials will be needed to construct the final ET cover. This section discusses the characteristics of materials needed for the various components of the ET cover and the most likely sources for these materials. Many potential sources of soil and rock materials exist, including both off-site commercial quarries and on-site borrow areas at RFETS. The preferred sources of materials are those that provide the needed materials in sufficient quantities and also help attain RFETS environmental restoration objectives. Final determinations of the suitability and source of materials will require additional investigation and testing of these materials and design optimization to accommodate the properties of available materials within the ET cover design.

Many of the materials for use in the soil-rooting medium, erosion protection, and methane-venting layers are available on-site. The conceptual design plans for the use of on-site materials to achieve multiple RFETS site closure objectives and provide a cost-effective design. Materials that will be obtained from off-site sources include synthetic materials used in the methane-venting system, seed mix, and possible soil amendments.

3.3.1 Previous Borrow Source Evaluation

A report entitled *Borrow Source Evaluation for Closure of the OU5 and OU7 Landfills* was prepared for the U.S. Department of Energy by EG&G Rocky Flats, Inc. (1994). The report addresses the Original Landfill (previously referred to as OU5) and the Present Landfill (previously referred to as OU7). This study examined potential soil borrow sources for final cover construction, based on a final cover design consisting of a 2-foot thick, low-permeability soil barrier layer, along with structural soil fill and topsoil. Both on-site and off-site borrow sources were considered, and material types and costs for a variety of potential borrow sources were compared. The report gives detailed consideration of off-site borrow sources, haul distances, and costs, and looks closely at existing commercial quarries.

The 1994 borrow source evaluation found that on-site soils were likely to provide the lowest cost construction, because the cost of transporting off-site materials quickly outweighs all other cost factors when haul distances reach more than a few miles. The report also raises the issue of royalty payments to the holders of mineral rights at RFETS.

3.3.2 *Soil-Rooting Medium and Erosion Protection Layers*

Performance modeling with UNSAT-H, discussed in more detail in Appendix A, shows that a minimum 18-inch thickness is required for the soil-rooting layer to support vegetation and to provide adequate soil moisture storage to prevent significant infiltration through the cover. The minimum thickness for the combined soil-rooting medium and erosion protection layers will be 30 inches, with an average thickness of approximately 50 inches, based on the cover layout design grades.

Typical rooting-medium soils for ET cover applications are sandy, silty, or clayey loams that contain significant fines (passing No. 200 sieve) to provide good moisture storage characteristics. The design thickness of the soil-rooting medium is variable depending on the moisture retention characteristics of the selected soils. An advantage of the ET cover is that a fairly wide range of rooting-medium soil properties may provide satisfactory performance.

Erosion rate calculations for the ET cover conceptual design using RUSLE are presented in Appendix F. The RUSLE erosion model was developed by the U.S. Department of Agriculture and is presented in Renard, et. al. (1997). In addition, independent erosion calculations are being completed by KH using the Watershed Erosion Prediction Project (WEPP) model.

The required thickness of the erosion protection layer varies depending on slope grades and lengths. Most of the cover requires a 6-inch-thick erosion protection layer. The steeper side slopes of up to 14 percent require a minimum 12-inch thick erosion protection layer to resist erosion over the 1,000-year design life.

The erosion protection layer is expected to consist of soils similar to the soil-rooting medium, with specifications for the size and percentage of gravel and cobbles. Rocky soils with appropriate characteristics may be identified that can be excavated and used directly for this purpose. For example, as discussed below, the soils available on-site at RFETS and from the nearby LaFarge Quarry show strong development and long-term stability. They also contain a large percentage of gravel and cobble-sized particles, making these soils well suited for the erosion protection layer. Alternatively, soils may be augmented with additional rock as needed.

Rock screened from on-site soils or from a variety of off-site commercial sources is suitable for this application.

Local soils possess the appropriate characteristics for the ET cover soil-rooting medium and erosion protection layer. The Flatirons Series surficial soils and Rocky Flats Alluvium in the shallow subsurface contain loamy soils with a significant clay fraction, which provide good moisture retention characteristics. The on-site soil and alluvium also contains a large fraction of cobble-size rock, which can be used to reinforce the upper erosion protection layer.

As indicated in a previous study (EG&G, 1994), a variety of soil borrow source locations may be considered as sources of suitable soil for construction of the ET covers over the Present Landfill. On-site and nearby soils at RFETS or off-site commercial quarries appear suitable based on initial laboratory testing and modeling results. Numerous factors must be considered in selecting the final soil borrow source, and final recommendations are not part of this materials report. Final decisions on the soil borrow source location will be made after material specifications are developed and more extensive soil testing is completed.

Additional subsurface investigation and geotechnical testing of potential soil borrow sources will be needed at the final design stage. Whatever final borrow source is selected, suitable soils will be available within reasonable haul distances to keep construction costs to a minimum. As recommended in the 1994 borrow source evaluation, competitive bids should be solicited either for off-site purchase and transportation or on-site excavation and regrading in order to obtain the most favorable terms.

Because the soil-rooting medium and erosion protection layers comprise the most significant material quantities in the cover, use of a nearby borrow source will minimize haul distances and provide cost advantages. With this in mind, two potential sources were examined: the nearby LaFarge Quarry and an on-site soil source. Both the LaFarge and on-site soils include the Flatirons Series soils and Rocky Flats Alluvium. On-site soils at RFETS in the vicinity of the Present Landfill are expected to have geotechnical and hydrologic properties similar to the soil tested from the LaFarge Quarry, which is described in more detail below. Soils at RFETS consist primarily of Flatirons Series soils developed on the Rocky Flats Alluvium, with lesser areas of Nederland and Veldkamp Series soils (Price, 1980). These soil types are described as very cobbly or very stony sandy loam. Flatirons soils are described as having low permeability due to significant clay, with rooting depths of 60 inches or more. Soil descriptions of these series are provided in Appendix G.

3.3.2.1 LaFarge Quarry Materials Source

An investigation was conducted to characterize, sample, and test the typical borrow soil available at RFETS for possible use in constructing the ET cover. Soil was sampled from the LaFarge Quarry adjacent to the northern RFETS boundary, where borrow soil may be obtained during cover construction. A total of nine samples were collected from a "select fill" soil stockpile at the quarry. The LaFarge Quarry select fill is the finer portion of soil remaining after larger cobbles and gravel are separated by screening for commercial purposes. It has minimal commercial value, and is used primarily to backfill excavations on-site.

The nine soil samples were tested at Advanced Terra Testing, Inc. (ATT) in Lakewood, Colorado. Samples underwent the following tests:

- Standard Proctor compaction
- Grain-size distribution (sieve and hydrometer)
- Saturated hydraulic conductivity
- Moisture retention characteristic curves
- Atterberg limits
- Consolidation
- Triaxial compression

One of the nine samples underwent verification testing at the DBS&A Hydrologic Testing Laboratories in Albuquerque, New Mexico. This testing involved two subsamples that were compacted to varying densities in the laboratory to simulate the typical compaction range experienced during construction activities. The soil is characterized as a sandy loam using the USDA Soil Classification and a clayey sand with gravel using the ASTM Soil Classification. A summary of the results are included in Appendix H.

The LaFarge Quarry soils tested represented the finer portion of the soil, with gravel and large-sized particles removed. Soil properties for typical on-site soils containing gravel and cobbles will need to be determined. On-site soils may also be processed to remove these large particles, if needed to satisfy final soil specifications. Gravel and cobbles removed from the soil-rooting medium may also be used to augment the cover's erosion protection or gas-venting layers.

3.3.2.2 Present Landfill Materials Source

The primary borrow source location being considered for closure of the Present Landfill is an on-site area located at the eastern edge of the Present Landfill. The conceptual design provides an option for a treatment area of approximately 6 acres east of the Present Landfill. The area will be recontoured as an extension of the Present Landfill ET cover and serve as an ET apron to eliminate the current seep at the eastern toe of the landfill (Figures 4 and 11). The recontouring will provide a source of sufficient soil quantities for ET cover construction over the Present Landfill, and the ET apron size and elevation can be designed to provide a soil balance to match excavation and cover soil quantities. Use of borrow materials from the ET apron can provide a cost-effective approach because of its proximity to the Present Landfill.

Several issues that need to be addressed in greater detail before moving forward with the use of on-site borrow materials include:

- Geotechnical investigation of the optional ET apron
- Determination of mineral royalty fees
- Permitting and environmental requirements

These issues will need to be addressed as part of the decision document for site closure and in the final design.

3.3.3 Coarse Aggregate

Coarse aggregate may be obtained from on-site soils or off-site commercial sources. Course aggregate is needed for two components of the ET cover:

- Landfill gas-venting layer
- ET apron water distribution trenches

A fairly wide range of particle sizes may be suitable for these applications, ranging from pea-gravel to cobble-sized rock. Depending on the gas-permeability of the material, the gas-venting system design will need to be optimized to provide the appropriate pipe and vent spacing for the expected gas flow rates and most economical coarse material. Similarly, the ET apron water distribution trenches will require design optimization to establish trench spacing and sizing in conjunction with the permeability characteristics of the coarse aggregate.

Whether from on-site or off-site sources, the coarse aggregate is expected to be a processed material that has been screened to a specified size gradation. This type of screening operation can be cost effectively set up for short-term operation on-site, when significant quantities of aggregate are required.

3.3.4 Synthetic Materials

Synthetic materials used in the Present Landfill gas-venting system will be obtained from commercial, off-site suppliers. These materials need only limited longevity, until gas generation rates decline and waste is fully degraded. The synthetic materials used in the gas-venting layer include:

- Geotextile separation fabric
- High-density polyethylene (HDPE) piping (perforated, solid, and fittings)
- Landfill gas vents (HDPE, steel, or other materials)

Because many commercial providers of these materials are available, the costs are reasonable and competitive, and will be a minor portion of the overall construction costs. The conceptual design for the gas-venting system includes materials with typical geotextile strength, pipe sizing, vent types, etc.

3.3.4.1 Geotextile Separation Fabric

A geotextile separation fabric will be needed for construction of the gas-venting layer, to prevent fine particles from the overlying soil-rooting medium from clogging the coarse aggregate. A non-woven geotextile fabric, 8 to 12 ounces per square yard, or similar material, will fulfill this application. The geotextile separation fabric, with seams sewn to connect the fabric panels, will be placed over coarse aggregate.

Final design specifications for the geotextile separation fabric will depend on the particle-size gradation of both the underlying coarse aggregate and overlying soil-rooting medium. The appropriate geotextile strength will depend on the maximum particle size and particle angularity of the overlying and underlying materials. Tensile strength and elongation design requirements must also be considered to accommodate long-term waste settlement.

3.3.4.2 Piping and Vents

The methane-venting piping network will consist of perforated, 2-inch diameter, dimension ratio (DR)-17, HDPE pipe. Welded HDPE is the most common pipe material used for landfill gas collection systems due to its strength, flexibility, compatibility with landfill gas and condensate, and ability to withstand the forces of differential settlement over landfills.

The gas collection piping will be connected to a series of passive gas vent standpipes. The vent piping may be either HDPE or steel. The vents will need to be designed in a manner compatible with the planned open space land use and institutional controls that will be in place at the site. A U-tube vent that allows gas to escape and prevents entry of precipitation is the most common design. Vertical standpipes provide better gas-flow performance than U-tubes, because the chimney effect of wind movement across the standpipe creates a low-pressure driver to draw gas from the well. The small amount of precipitation that may enter a vertical standpipe is minimal within the overall cover water balance. A screen may be placed over the end of the vent, as needed, to prevent entry of animals or any foreign matter. A wind-driven turbine may also be added to the vent to increase air flow. Depending on the degree of public access and gas quality and emission rates, the vents may be extended to a height of 8 to 10 feet to minimize any gas exposure to the public and to avoid explosive accidents. Shorter 3-foot vents may be utilized if public access is restricted.

3.4 Material Quantities

Material quantities needed for construction of the ET cover have been calculated based on the conceptual design of final cover contours as shown in Figures 4 and 11. Soil and rock components make up a majority of the materials used in cover construction, and volume estimates for these materials are based on the design thickness of these components as shown in the cover details in Figure 6. The conceptual design provides reasonable estimates of the material quantities needed. The quantities will be refined during the final design process to optimize performance and cost factors.

3.4.1 Estimated Quantities of Materials for Construction

Material quantities for the construction materials described above are provided in Tables 6 [KA18](cover asbestos in place) and 7[KA19] (relocate asbestos). These tables provide details of the design assumptions used to estimate material quantities. In addition to the construction materials, several line items have been identified in the tables to show complete construction activities typically included in construction cost estimates. These items are described more fully in the construction cost estimate in presented in Section 9.

The material quantities provided are based on the conceptual cover design contours, and details are provided for assumptions made in determining quantities. During conceptual design, basic requirements for material properties, layer thicknesses, gas-venting system, and ET apron layout were planned using reasonable assumptions and dimensions. Further engineering design refinement and optimization will be needed to reach the final design stage.

3.4.2 Soil Balance

Designing for a soil balance is a critical element of a cost-effective design. Soil removed from the ET apron at the Present Landfill may be regraded over the Present Landfill. The two cover grading plan options shown in Figures 4 and 11 have very different soil balance outcomes, as summarized in Table 8.

Table 6. ET Cover Material Quantities for Present, Cover Asbestos In-Place Option
Rocky Flats Environmental Technology Site

Item	Unit	Quantity	Description
Mobilization/demobilization	LS	1	Construction contractor and equipment mobilization and demobilization.
Construction staking	AC	42.8	Surveyor staking for construction grade control.
Clear and grub construction areas	AC	42.8	Remove vegetation from borrow and cover areas. On-site disposal at Present Landfill.
Excavation	CY	199,162	Excavation from on-site borrow source.
Soil processing/screening	CY	160,695	Screening rock on-site for erosion protection layer, gravel for landfill gas venting layer, and ET apron trenches.
Soil transportation, on-site	CY	360,127	Regrading from ET apron to Present Landfill.
Erosion protection layer	CY	50,870	Soil and rock placement and grading, minimum 12-inch thickness.
Soil rooting medium - on-site	CY	127,831	Soil placement and grading. Minimum 18-inch thickness, typically 2 to 3 feet.
Soil rooting medium - off-site	CY	247,510	Purchase from off-site source, 10 mile round trip haul, place w/dozer
Excavate — ET apron trenches	CY	3,970	Excavate trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — ET apron trenches	CY	3,970	Gravel filled trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — gas venting layer	CY	16,491	Placement and grading of processed gravel from on-site borrow, 6-inch thickness.
Perforated HDPE pipe — 2-inch diameter	LF	10,000	Gas venting passive collection piping, 100-foot spacing, 20.4 acres.
Solid HDPE pipe — 4-inch diameter	LF	4,675	Gas venting system pipe and fittings on landfill perimeter.
Revegetation	AC	47.1	Native seed mix, drill seeding, and soil amendment, includes additional 10% beyond construction limits.

LS = Lump sum
AC = Acre
CY = Cubic yards
ET = Evapotranspiration
HDPE = High density polyethylene
LF = Linear feet

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Table 7. ET Cover Material Quantities for Present Landfill, Relocate Asbestos Option
Rocky Flats Environmental Technology Site

Item	Unit	Quantity	Description
Mobilization/demobilization	LS	1	Construction contractor and equipment mobilization and demobilization.
Construction staking	AC	41.25	Surveyor staking for construction grade control.
Clear and grub construction areas	AC	41.25	Remove vegetation from borrow and cover areas. On-site disposal at Present Landfill.
Strip and stockpile	CY	18,187	Remove upper 12 inches of soil from borrow area and stockpile for cover
Excavation	CY	251,715	Excavation from on-site borrow source.
Soil processing/screening	CY	175,982	Screening rock on-site for erosion protection layer, gravel for landfill gas venting layer, and ET apron trenches.
Soil transportation, on-site	CY	427,697	Regrading from ET apron to Present Landfill.
Erosion protection layer	CY	42,665	Soil and rock placement and grading, minimum 12-inch thickness.
Soil rooting medium, on-site	CY	169,459	Soil placement and grading. Minimum 18-inch thickness, typically 2 to 3 feet.
Excavate — ET apron trenches	CY	3,970	Excavate trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — ET apron trenches	CY	3,970	Gravel filled trenches: header trench, 5 feet wide by 10 feet deep by 800 linear feet; lateral trenches, 3 feet wide by 8 feet deep by 2,000 linear feet with 100-foot spacing over west half of ET apron; footer trench, 3 feet wide by 8 feet deep by 800 linear feet.
Gravel — gas venting layer	CY	12,738	Placement and grading of processed gravel from on-site borrow, 6-inch thickness.
Perforated HDPE pipe — 2-inch diameter	LF	8,000	Gas venting passive collection piping, 100-foot spacing, 15.8 acres.
Solid HDPE pipe — 4-inch diameter	LF	3,911	Gas venting system pipe and fittings on landfill perimeter.
Excavation and relocating asbestos	CY	12,395	Excavation of asbestos and consolidation within the central landfill area, 10-foot depth, 0.8 acres.
Regrading solid waste	CY	32,800	Regrading waste and intermediate cover to reduce disposal cell height to improve cover slopes, 3.3-foot average depth, 8.4 acres.
Revegetation	AC	45.4	Native seed mix, drill seeding, and soil amendment, includes additional 10% beyond construction limits.

LS = Lump sum
AC = Acre
CY = Cubic yards
ET = Evapotranspiration
HDPE = High density polyethylene
LF = Linear feet

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Table 8: Soil Balance Summary for the Present Landfill ET Cover

Cover Design Option	Soil Quantity Required [a] (cubic yards)	Soil Quantity Excavated from ET Apron [a] (cubic yards)	Net Import/Export (cubic yards)
Cover asbestos in-place	446,672	199,162	247,510 Import
Relocate asbestos	228,832	292,275	63,443 Export

[a] Total soil quantity includes erosion protection layer, soil-rooting medium, and gravel for gas-venting layer and ET apron flow distribution trenches.

The conceptual design grading plan requires a significant import of soil for the primary option to cover asbestos in place. The secondary option, to relocate asbestos, can create a significant excess of soil for possible export for other uses at RFETS. The secondary option can also provide a soil balance through adjustments to the grading plan to best meet the final design objectives.

The ET apron excavation quantity differs for the two options because the location and configuration of the ET apron changes for the two options, and the grading plan must change to tie-in the ET apron with surrounding native topography. Also, the size of the ET apron differs for the two options. For the primary option (covering the asbestos in place), the ET apron is 6 acres. For the secondary option, (relocating the asbestos), the ET apron was expanded to 7.5 acres in order to examine the potential to generate additional on-site soil. If the Present Landfill is addressed alone, the ET apron size and configuration may be optimized to achieve a soil balance.

The preliminary soil balance assumes that soil placed on the covers will have the same density as native soils removed from the on-site borrow source. However, a volume increase or swell factor of 5 to 10 percent may occur from excavated bank volume to in-place volume of placed soil. The final soil balance will need to be based on site-specific soil testing that reflects differences in density, so that such differences are accounted for in the final design.

The soil balance between borrow and fill areas can be adjusted as the design is refined and optimized in the final design process. Slight changes to the layout of the ET apron will provide flexibility in the soil borrow quantity. For example, raising or lowering the elevation of the ET

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apron by a few feet, or expanding the 6-acre apron area, creates substantial adjustments to the soil borrow quantity. Thus, the conceptual design approach incorporates a built-in mechanism to optimize the final design with regard to quantities and costs.

4. Vegetation Plan

Control of infiltration through the proposed vegetated soil covers at the Present Landfill is key to an effective cover design. The current revegetation strategy at RFETS is to restore the native prairie grasslands as closely as possible to preexisting conditions. Considerable information on vegetation has been assembled by ecologists at RFETS, and this plan draws directly from revegetation guidelines for RFETS and from correspondence with the KH Ecology Group (KH, 2001).

4.1 Seed Mix

Seed mix will be procured from an off-site source based on seed specifications that meet KH Ecology Group requirements. Specific seedbed preparation, seeding, mulch application, and weed control should follow existing RFETS guidelines, and the revegetation plan should be prepared or reviewed by site ecologists. Because local native seed availability varies from year to year, the proposed mixture should be reviewed before seeding to reconcile any potential discrepancies between functional requirements and seed availability.

Native upland vegetation at RFETS varies from xeric tallgrass prairie to mesic mixed grass prairie. The largest portion of the tallgrass prairie is dominated by the native grasses *Andropogon gerardii*, *Muhlenbergia montana*, *Andropogon scoparius*, and *Stipa comata*, with *Koleria pyrimidata*, *Bouteloua hirsuta*, and *Bouteloua gracilis* also common. Another xeric grassland type is the needle-and-thread grass community, which is dominated largely by the native species, *Stipa comata*, with some occasional *Bouteloua gracilis.* The mesic mixed grassland is dominated by the native species *Agropyron smithii*, *Bouteloua gracilis*, *Bouteloua curtipendula*, and *Stipa viridula*. These communities should be specified in a final seed mix at the time of final design.

A mixture of warm and cool season plants should be used for effective control of infiltration. Cool season plants such as native western wheatgrass, green needle grass, and most forbs green up in early spring and rapidly transpire water accumulated in the soil profile during winter. Warm season plants, such as native grama and bluestem grasses, transpire more effectively during the warm summer months. Native prairies at mid-latitudes such as RFETS always have a mixture of both warm and cool season vegetation. The specified seed mix should be adaptable to microclimates such as those on north- or south-facing slopes.

A mixture of plants with varying rooting strategies and depths should be used. In general, cool season grasses have a more fibrous root system, while warm season vegetation is more deeply rooted. Root systems can make up 90 percent of a plant's biomass. The key vegetation design requirement is that available soil water will be fully used by the plant community during the growing season. The key soil requirement is that enough soil water storage be available to store precipitation while plants are dormant (approximately October to March). This is achieved by having roots actively uptake water at different depths and times, which means a mixture of warm and cool season grasses with varying rooting depths.

Plant cover must also provide erosion control. Site revegetation mixtures use a combination of warm and cool season grasses, as well as bunch and rhizomatous or sod-forming species. This combination has provided empirical on-site success. Native grasses at RFETS are both bunchgrasses and rhizomatous grasses. Native rhizomatous grasses include *Agropyron smithii*, *Bouteloua gracilis*, and *Buchloe dactyloides*. Native bunch grasses include *Andropogon gerardii*, *Andropogon scoparius*, *Stipa comata*, *Stipa viridula*, and *Bouteloua curtipendula*.

4.2 Soil Amendments

Soil amendments may be considered as an option to aid in establishing vegetation on the ET cover. If the erosion protection layer and soil-rooting medium are composed of a mix of both topsoil and Rocky Flats Alluvium, the material may be relatively poor in organic matter and nutrients. Testing for soil nutrients should be conducted and decisions made regarding the value of adding soil nutrient amendments to improve revegetation efforts.

Selection of soil amendments should be investigated more fully near the time of construction, because local availability of sludge, compost, and agricultural fertilizers can change rapidly depending on local government and commercial recycling programs. Possible soil amendments may include commercial fertilizer, compost, sewage sludge, manure, or other agricultural wastes. Avoiding unwanted introduction of weed seeds will be an important consideration in selecting soil amendments. Final recommendations for any soil amendments should be made in consultation with the KH Ecology Group.

4.3 Revegetation Plan for Cover and Disturbed Areas

All of the ET cover and any surrounding areas disturbed by construction activities will be revegetated. The optional ET apron, if used, will be revegetated as well. Revegetation activities will most likely take place as the last phase of construction activities; although revegetation may be postponed, if needed, depending on the season when construction is completed.

Initial establishment of vegetation will occur during the first year after seeding; however, it will take up to approximately five years for vegetation to become well established. When vegetation is fully established, plant roots will completely penetrate the ET cover erosion protection layer and soil-rooting medium. Only when vegetation is fully established, will the ET cover reach its full performance in minimizing infiltration.

Either drill-seeding or hydro-seeding may be considered, hydro-seeding is the method most commonly used for landfill revegetation efforts, because it is rapid and can work effectively on slopes. The ET cover slopes are gentle, and drill-seeding equipment can be operated on these areas as well. Due to the importance of vegetation on the ET cover, the best suited technical approach must be selected.

Small grass and forb seeds are often difficult to establish in semi-arid climates. Poor stands lead to longer establishment times and typically allow more wind and water erosion, as well as weed establishment, with attendant increased maintenance costs. Using a durable mulch to protect soil from erosion and to protect seedlings from desiccation would be advisable under conditions commonly experienced at RFETS.

Irrigation is an option for improved seed germination and establishment of plant stands on the landfill covers. Without irrigation, seeding may fail in dry years, which can result in additional establishment and maintenance costs. Depending upon the year, irrigation may be needed over large or small areas.

Water from the seep or from the landfill feeding the seep is a potential source of water. Seep water quality is more than adequate for irrigation and no irrigation will be done outside the footprint of the landfill. The decision to irrigate with seep water must be made at the time of seeding based upon soil and weather conditions. In most circumstances, a single season of irrigation is likely to be adequate. Under severe drought conditions, irrigation may need to be extended.

Existing RFETS revegetation guidelines are consistent with the functional objectives discussed above. Specific seedbed preparation, seeding, mulch application, and weed control should follow existing guidelines, and the revegetation plan should be prepared or reviewed by site ecologists. Previously used seed mixes will effectively meet the objectives discussed above. Because local native seed availability varies from year to year, the proposed mixture should be reviewed before seeding to reconcile any potential discrepancies between functional requirements and seed availability.

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5. Erosion Control

The materials used in the ET cover consist primarily of native soil, gravel, and rock, which are not subject to significant long-term degradation and will meet the project design criteria for a 1,000-year design life. The soil-rooting medium and erosion protection layer consist entirely of this native, non-degradable material. Use of native vegetation will stabilize the cover soils in a manner that is expected to provide longevity and adaptability to environmental changes. As observed on-site, native vegetation promotes the formation of stable soil horizons.

The cover slopes must be designed to resist erosion to the extent that the design criterion for cover longevity is achieved. A design life of 1,000 years may be applied to the site based on RFETS objectives. Erosion resistance is improved by reducing cover slopes; however, this will lead to the eastern landfill slope impinging on the East Landfill Pond and wetlands.

The required thickness of the erosion protection layer will vary depending on slope grades and lengths. Most of the cover requires a 6-inch thick erosion protection layer. The steeper side slopes of up to 14 percent require a minimum 12-inch thick erosion protection layer to resist erosion over the 1,000-year design life. Erosion resistance will be enhanced by use of selected vegetation and rock armoring.

5.1 Soil Erosion Evaluation

Erosion rates were calculated for a range of cover slopes. The final determination of the maximum slope that can achieve the required erosion resistance and longevity, will dictate the extent to which the cover extends east of the landfill toward the East Landfill Pond.

The RUSLE model was used to calculate slope erosion for RFETS. RUSLE is a widely used model to predict soil loss on any field condition where soil erosion by water is possible (Renard, et al., 1997). Erosion rates were modeled for the cover configuration as shown on the landfill cover grading plan (Figure 4). The slope length and gradient were measured for several of the key transects on the Present Landfill and a range of values was used to examine erosion rates on varying slopes. (Figure 5).

Erosion modeling used site-specific values based on properties of the Flatirons Series soil at RFETS and climatic data for the Denver area. Model input parameters for erosion-index and the rainfall-runoff erodibility factor factors were derived from the isoerodent map for Colorado (Wischmeier, 1978) and the Agriculture Handbook #703. The RUSLE model uses these inputs to determine the erosion force of a specific rainfall event. Erosion losses from rainfall are calculated for the maximum 30-minute rainfall intensity.

As discussed in the storm water management plan (Section 6), the soil permeability is a key element affecting the amount of runoff generated during heavy precipitation events. The saturated hydraulic conductivity of potential off-site borrow soil for the soil-rooting medium was calculated from testing as 0.72 in/hr, and this value was used in the RUSLE erosion model. This value is conservative from the standpoint of predicting higher erosion rates. The final erosion protection layer surface soil will contain a significant amount of rock and gravel to have a permeability exceeding the permeability of the soil-rooting medium. Based on the runoff calculations in Appendix I, runoff is minimized for a surface soil permeability of approximately 3 in/hr or greater. Therefore, erosion may be controlled to a greater extent by selecting appropriate properties for the erosion protection layer for long-term erosion control performance exceeding the RUSLE model predictions.

The RUSLE soil erosion model allows for the input of local plant community characteristics, which was specified in the model as a short-grass prairie. It is assumed that after being established, the plant community will have a relatively constant amount of canopy cover, surface and subsurface residues, and root mass. The percent of surface covered by rock fragments was also used as input to the RUSLE model. The model inputs were consistent with published values for undisturbed rangeland.

The results for the RUSLE soil erosion modeling are provided in Appendix F. Using conservative input parameters, it will take approximately 1,400 years for 1 foot of soil to erode from the landfill on the steeper slopes (14 percent). The model was used to predict erosion from the existing east slope of the Present Landfill, which has a slope of approximately 30 percent. This steep slope will experience 1 foot of erosion in approximately 870 years, which is consistent with field observations indicating considerable gullying on this slope. The conceptual design reduces the east slope of the Present Landfill final cover considerably to minimize erosion and improve cover longevity.

5.2 Provision and Plan

Plans for erosion control have been evaluated through erosion rate modeling to demonstrate the feasibility of the ET cover to provide 1,000-year longevity. Provisions to minimize soil erosion are addressed by the ET cover conceptual design in the following ways:

- The cover grading plan for the landfill provides gentle slopes of 3 to 14 percent to minimize erosion.
- A 6-inch minimum and 12-inch maximum erosion protection layer will be constructed on the entire surface of the ET cover.
- The erosion protection layer will specify a significant fraction of rock and gravel-sized particles to resist both storm water and wind erosion.
- Well-established vegetation will stabilize the soil and prevent erosion.

The storm water management plan for the Present Landfill can handle intense storm events with minimal runoff and little impact to surrounding areas or the site-wide surface control system at RFETS. The plan reduces runoff to the extent that erosion can be controlled and long-term maintenance is eliminated.

5.3 Sediment Control During Construction

During construction, sedimentation due to storm water runoff must be controlled and standard sediment reduction practices will be required. These may include such measures as temporary sediment control (silt) fencing, diversion berms and/or catchment basins. Such structures will need to be inspected and maintained throughout the course of the construction. Some sediment control measures may also need to be maintained throughout the first year after construction has been completed, until adequate vegetation has been established to eliminate a need for further sediment controls.

6. Storm Water Management Plan

The storm water management plan for the Present Landfill ET cover is based on minimizing runoff and establishing a final cover that behaves very much like the undisturbed native grasslands at RFETS. The predominant performance consideration for the storm water control system is to minimize erosion to meet the design criterion for 1,000-year longevity. To meet this design life, storm water is controlled by dispersed, overland flow, rather than focusing flow in engineered storm water channels. Storm water will flow off of the ET cover on gentle grades ranging from 3 to 14 percent at the landfill. Storm water runoff from the gently sloping, vegetated ET cover will be nearly the same as runoff from the surrounding landscape. Runoff from the ET cover will not be impacted by contaminants and will be handled within the overall RFETS storm water control system.

6.1 Storm Water Design Approach

The conceptual design approach for storm water management is unique, since the ET cover promotes infiltration of storm water and minimizes runoff. Conventional runoff channels and detention basins are not part of the storm water design approach. The site grading plan has been designed to shed storm water relatively uniformly around the entire ET cover, eliminating any focused or channelized flow. Overland flow from the cover will be dispersed to surrounding areas and will not come in contact with waste materials or residual contaminants.

The ET cover design encourages infiltration in two ways:

- Topsoil is highly permeable
- Vegetation reduces downslope flow

Long steep slopes with native vegetation at RFETS show minimal erosion. The use of permeable, vegetated soils will allow infiltration of most precipitation and eliminate runoff in all but the most severe storm events.

The storm water management plan for the ET cover provides significant advantages over a conventional storm water control system that uses conveyance channels and detention basins. The conventional engineered design must overcome the following obstacles to meet the 1,000-year design criterion:

- Conveyance channels and detention basins must be sized for a 1,000-year or greater design storm
- Concrete structures cannot be used, because exposed concrete will degrade over time
- Structures must be oversized to the extent necessary to accommodate sedimentation
- Planned maintenance, typical of most engineered storm water systems, cannot be included in the design

The ET cover storm water management plan eliminates the need to address these issues.

The ET cover will shed relatively minor storm water runoff, which will be captured in the RFETS surface water management basins, downstream in No Name Gulch. Calculations for the amount of runoff expected are provided in the following section. Input parameters to the runoff calculation model were consistent with native terrain, which will be closely simulated by the ET cover.

6.2 Runoff Calculation Methods

Storm water runoff from the ET cover was calculated using two methods: (1) the Rational Method and (2) the Colorado Urban Hydrograph Procedure (CUHP). These runoff models use characteristic values for calculation that have been determined to be reasonably representative of local conditions. Each of the calculation methods is described below, followed by a discussion of the results.

6.2.1 Rational Method

The Rational Method is widely used for modeling small watersheds. Rational Method calculations used the Denver Urban Drainage and Flood Control District (DUDFCD) spreadsheet to automate the calculations and provide regional constants. Results of the spreadsheet calculation include:

- Computed time of flow concentration
- Regional time of flow concentration
- Rainfall intensity (in/hr)
- Peak flow rate (cubic feet per second [cfs])

The Present Landfill area was divided into six sub-basins based on slope and direction of overland flow, and the average flow path length and slope were determined for each of the six sub-basins. Sub-basin areas range from 1 to 12 acres at slopes of 4 to 14 percent. Soil and vegetation parameters representative of the ET cover design were selected to simulated native vegetation over soils that exhibit minimal compaction for good infiltration capacity.

Storm water runoff was calculated for design storms with return periods of 100 and 1,000 years. Maximum runoff was calculated for the most intense 1-hour storm events, which are representative of extreme downpours. The one-hour precipitation for the 100-year storm was determined to be 2.7 inches from the 100-year, one-hour rainfall chart included in the DUDFCD *Drainage Criteria Manual* (DUDFCD, 2001). To determine the 1-hour precipitation value for a 1,000-year storm, the one-hour precipitation values from the 2-, 5-, 10-, 25-, 50-, and 100-year charts were graphed, and the 1,000-year, 1-hour precipitation value was extrapolated to be 3.7 inches. For the landfill, peak runoff rates of 59 cfs and 80 cfs were calculated for the 100-year and 1,000-year storm events, respectively.

6.2.2 Colorado Urban Hydrograph Procedure

The CUHP is a method of hydrologic analysis based on the unit hydrograph principle. It has been developed and calibrated using rainfall-runoff data collected in Colorado (mostly in the Denver/Boulder metropolitan area). The CUHP method differs significantly from the Rational Method in that soil infiltration rates may be selected by the modeler. In this case, an infiltration value of 3 in/hr was selected, which is in the range expected for the ET cover erosion protection layer.

Storm water runoff was calculated by the CUHP method for the same 100- and 1,000- year design storms with maximum runoff from intense 1-hour storm events. Again, these 1-hour storm events were assumed to result in 2.7 and 3.7 inches of rain, respectively. The peak runoff rate for the landfill was calculated as 1 cfs for the 100-year storm, while the peak runoff rate was calculated at 48 cfs for the 1,000-year storm.

6.2.3 Discussion of Results

As seen above, predicted storm water runoff flow rates vary widely between the Rational Method DUDFCD spreadsheet and the CUHP. The Rational Method uses a generalized input to characterize soil and vegetation properties, while the CUHP model uses direct input of the soil infiltration rate. The model results are very sensitive to this input, and thus, give very different results. Runoff model results are summarized in Table 9.

Table 9: Summary of Runoff Calculations for the Present Landfill ET Cover

Storm Event Recurrence Interval	1-Hour Design Storm Precipitation (in/hr)	Area (acres)	Peak Flow Rate (cfs)
Denver Urban Drainage and Flood Control District (DUDFCD) Rational Method Spreadsheet			
100-year	2.7	43.7	58.8
1,000-year	3.7	43.7	80.2
Colorado Urban Hydrograph Procedure (CUHP)			
100-year	2.7	43.7	1
1,000-year	3.7	43.7	48

The CUHP model demonstrates the effect of soil permeability on runoff flow rates. Sufficient surface soil permeability allows nearly complete infiltration of all precipitation from a 1-hour, 100-year storm event. Only the rare 1,000-year storm event leads to significant runoff. Nearly all of the precipitation from smaller storm events will infiltrate, and will provide soil moisture to sustain the ET cover vegetation. While the two methods of calculation give significantly different results, the most credible evidence to guide design is the presence of similar stable native slopes nearby with the same soils and vegetation.

6.3 Provision and Plan

The storm water management provisions for the ET cover will be addressed not only through engineering design features, but also with careful consideration of soil and vegetation properties to minimize storm water runoff. The conceptual design includes the following storm water provisions:

- The cover slopes are 3 to 14 percent.
- Cover grades are crowned outward (convex) to disperse and distribute overland flow and shed water to surrounding areas.
- Areas of focused or channelized flow are eliminated.
- The erosion protection layer will have sufficient permeability to infiltrate nearly all precipitation and minimize runoff
- ET cover vegetation will be supported by capturing precipitation with the vegetation further controlling runoff and erosion.

Based on the modeling, the proposed storm water management plan for the Present Landfill can handle intense storm events with minimal runoff and little impact to surrounding areas or the site-wide surface control system at RFETS. The storm water management plan reduces runoff to the extent that erosion can be controlled and long-term maintenance is eliminated.

7. Monitoring Plan

The overall monitoring approach will use a phased program of action monitoring and performance monitoring. A phased approach allows more intensive monitoring in early years during vegetative establishment and characterization of the newly engineered system. Monitoring intensity will decrease over time as understanding of system behavior increases. Performance monitoring is driven by RFCA-imposed standards based primarily on surface water standards. The purpose of action monitoring is to anticipate performance failure before it happens. Thus, action monitoring of the cover should provide information on water storage and movement in the installed final cover to determine if there will be a negative impact at the performance monitoring locations.

7.1 Phased Monitoring Program

During Phase I intensive monitoring, a relationship will be established between the water balance in the cover and RFCA performance. Phase II will link visual observations of vegetation to the cover water balance through water-potential monitoring and numerical modeling. Vegetation and water-potential monitoring will continue on the covers and the grassland locations. Phase III, if needed, will continue system performance monitoring, maintenance, and vegetation monitoring as needed for a duration to be determined at the end of Phase II.

7.1.1 Action Monitoring

The simplest and most useful monitoring on the cover is a basic inspection and maintenance program. This program will start following completion of the final cover. Testing and inspection of the cover will include as-built sampling of the covers, periodic visual inspection of surface water controls, vegetation quality, weeds, seepage, burrowing animals, subsidence, and erosion. As-built soil sampling of the covers for physical and hydraulic properties will include bulk density, particle size, water-holding capacity, and hydraulic conductivity. The maintenance program will include weed control using mowing and/or herbicides, reseeding of bare areas, filling and regrading of subsidence zones to maintain positive drainage, and repair of eroded

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areas or storm water control features. A separate and detailed inspection and maintenance schedule for the site will be developed during the final design phase of the project.

Action monitoring consists primarily of monitoring components of the cover water balance. The information from action monitoring is used to assess the hydrologic performance of the cover based upon in situ measurements of soil properties and water and gas fluxes. This hydrologic performance assessment is used, in turn, to support attainment of RFCA performance standards. Monitoring of the cover water balance at the Present Landfill will include measurement or calculation of soil water content, soil-water potential, unsaturated water flux, temperature, and soil gas composition. Weather data will be collected on-site and will be available throughout the monitoring period.

7.1.2 Performance Monitoring Locations

For RCRA units, monitoring should occur at or near the boundary of the unit. Point(s) of compliance (POCs) being considered at the Present Landfill include performance monitoring locations at the toe of the regraded east slope near the existing seep. Surface water flow at the seep will be quantified and water quality monitored. In accordance with RFCA Attachment 10, Page 10-1, final POCs will be determined after the cap/cover has been installed.

7.1.3 Methane Monitoring

Landfill gas monitoring is considered an option to the monitoring program, which may be needed to meet RFETS air quality requirements. The landfill gas monitoring is not necessarily a fundamental component of the primary monitoring program aimed at determining the ET cover infiltration reduction performance. Potential landfill gas air quality impacts have not been evaluated as part of the ET cover conceptual design, but a more detailed determination of the regulatory requirements for possible landfill gas monitoring should be undertaken.

If needed, the landfill gas vents provide monitoring locations where landfill gas may be sampled. Small sampling ports may be installed in the gas vent standpipes to allow simple sample collection. Because diurnal and barometric pressure changes affect the flow of landfill gas out

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of the landfill and air flow into the landfill, a time-weighted monitoring approach is needed to characterize the overall gas concentrations and air emissions over time. Landfill gas measurements should be collected periodically over the course of one or more days, and the time of sampling recorded; alternately, dedicated instruments may be set up with dataloggers to continuously record gas concentrations over a period of days.

Primary landfill gas monitoring is generally conducted with field instruments that measure concentrations of methane, carbon dioxide, and oxygen. A limited number of laboratory verification samples may be collected in Tedlar bags for analysis of these parameters using EPA method 3C. Testing for NMOCs, VOCs, and/or HAPS is conducted by laboratory methods. Landfill gas samples for these organic constituents are collected in Summa canisters to preserve sample integrity.

Monitoring for landfill gas concentrations within the ET cover soil may be added to the monitoring program as an option if portions of the Present Landfill ET cover appear to show signs of stressed vegetation, which may be caused by a poorly oxygenated root zone. Soil gas samples can be collected by driving a small diameter (¼- to ½-inch) soil gas sampling probe into the soil to collect gas samples through a slotted tip. Both manually operated and automated probe systems are available. The soil gas investigation will most likely be interested only in field measurement of methane, oxygen, and carbon dioxide concentrations. When driving the probe, care is needed not to penetrate the gas-venting layer and the geotextile filter fabric at the top of the layer. The depth to the gas-venting layer will be variable across the cover.

7.2 Instrumentation

7.2.1 Heat dissipation sensors

Heat dissipation sensors (HDSs) will be used to monitor soil-water potentials and temperatures and also can be used to calculate water storage, percolation, and soil water content, and temperature gradients. HDSs infer soil-water matric potential from thermal conductance measurements of a ceramic matrix that is in hydraulic equilibrium with the surrounding soil

(Campbell et al., unpublished manuscript). The water potential range is approximately -0.2 to -100 bar with a sensitivity that is proportional to water potential.

7.2.2 Time-Domain Reflectometers

The process of sending pulses through a cable and observing the reflected waveform is called time-domain reflectometry (TDR). The type of material surrounding the conductors influences a waveform traveling down a coaxial cable or waveguide. If the dielectric constant of the material or medium surrounding the conductors is high, the electronic signal propagates more slowly. Because the dielectric constant of water is much higher than most materials, a signal within a wet or moist medium propagates slower than in the same medium when dry. Ionic conductivity affects the amplitude of the signal but not the propagation time. Thus, moisture content can be determined by measuring the propagation over a fixed-length probe embedded in the soil medium being measured.

A major advantage of TDR for soil moisture content measurement is the ability to fully automate the system. Additionally, once installed the system can have a long life span. Accuracy in many soil types is very good. A TDR system's accuracy, in general, is about the same as that for neutron probes (Schofield et. al., 1994).

Recent developments in TDR instrumentation have resulted in a TDR unit that connects directly to a datalogger. Calibration similar to the traditional TDR system is required for best results. This TDR water content reflectometer consists of two stainless steel rods connected to a printed circuit board. A five-conductor cable is connected to the circuit board to supply power, activate the probe, and monitor pulse output.

Oxygen will be monitored in the profile using Figaro KE-25, or similar sensors. LFG measurements showed that parts of the existing intermediate cover are low in oxygen. Five sensors will be installed in each of the two monitored cover profiles.

7.2.3 Lysimeters

Soil lysimeters are used for collecting deep drainage or percolation data and estimating recharge. The most commonly used lysimeter in covered systems is a simple variation of the soil lysimeter called a pan lysimeter. The pan lysimeter is an impervious pan installed beneath or within the soil in the plot of interest. Water collected in the pan drains to a collection system where it is subsequently quantified. There are numerous designs of lysimeters, however, they are typically less than 6 feet in depth. Fort Carson lysimeters are 4.5 feet in depth and RMA lysimeters vary from 3.5 to 5 feet in depth. The rate of soil water collected per unit area monitored is extrapolated and used to estimate the percolation rate of the entire cover system.

Lysimeters are not recommended at the Present Landfill because methane levels are high enough to affect rooting depths, transpiration rates, and cover performance. A lysimeter located away from the landfill would not be subjected to landfill gases and satisfactory lysimeter performance would not be indicative of final cover performance or provide an alert to possible performance failure of the system. Similarly, because lysimeters are sealed on the bottom, a lysimeter installed on the final cover would not be subjected to landfill gas flux. Thus, lysimeters would provide a misleadingly optimistic assessment of performance at the Present Landfill.

7.3 Monitoring Phases

Required performance monitoring at the Present Landfill is based upon a surface water standard (RFCA, Attachment 10). The cover system conceptual design will reduce infiltration through the cover by increasing transpiration and maintaining positive drainage. The intent is to meet performance requirements by eliminating all seepage from the landfill.

The seepage rate currently averages 2-3 gallons per minute (gpm) at the toe of the east slope of the landfill. For long-term erosion stability, the east slope of the landfill will be reduced to 14 percent. This reduction of the eastern slope will move the expression of any surface water several meters farther east, and the surface water monitoring location will be moved to correspond to the first surface appearance of water. In addition, the evapotranspiration apron below the landfill will be monitored for surface water and seeps. The facility will be observed for

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surface water on a quarterly basis and all observed locations of surface water will be sampled separately and tested as specified in RFCA.

7.3.1 Phase I: Intensive Monitoring, First 6 Years

Phase I will require a minimum of six years of data collection after vegetation is established on the cover. The intent of the Phase I effort is to obtain an understanding of the cover water balance and to gain understanding that will aid in the transition to a simple, cost-effective, long-term monitoring plan. A Phase I final report will be prepared within six months after completion of the six-year data collection period, and will include a data summary and interpretation, and a recommendation on whether to proceed to Phase II.

Standard inspections will be made monthly for the first two growing seasons following emplacement of the final cover (during establishment of vegetation), and quarterly for the last four years of this phase. Inspections will include observations of differential settlement, ponding, erosion, or changes in vegetation. Inspections for erosion will also be conducted after major precipitation events.

Action monitoring of the cover will provide information on water storage and movement. The information from action monitoring will be used to assess hydrologic performance of the cover. The information needed for this objective at the Present Landfill will be obtained from in situ soil measurements.

The as-built soil properties will be measured to determine relationships between soil water potential, soil-water content, and unsaturated hydraulic conductivity. Soil-water potential profiles and temperature profiles will be monitored using nested heat dissipation sensors. TDR probes will also be installed to obtain redundant information on water movement and storage within the profile.

HDSs will be installed following final cover construction at approximately 12-inch intervals within the cover and in the underlying waste. Two sets of HDSs will be installed on the Present Landfill cover, consisting of eight sensors each. Another set of HDSs will be installed near the seep monitoring location and will consist of eight sensors. Temperature and soil-water potential data will be collected daily using Campbell 23X dataloggers. Soil hydraulic and thermal properties of the cover will be measured or calculated from field and laboratory data.

TDR sensors will be placed at the same depths as HDS installations. These probes will provide independent information on performance (water content) in the cover profile and the ET apron.

Free oxygen is needed to sustain root growth and transpiration. Therefore, oxygen levels in the cover and the venting layer will be monitored at the two cover monitoring locations using Figaro KE-25 (or similar) oxygen sensors. Monitoring of oxygen levels may be discontinued when it is established the venting layer is functioning as designed.

7.3.2 Phase II: Intermediate Monitoring, Years Six 6 through 10

Phase II will continue all inspection and maintenance activities of Phase I. Observed infiltration through the ET cover during Phase II is anticipated to be near zero. Monitoring of the HDS and TDR profiles in the cover and seep monitoring location will be discontinued. Quarterly performance monitoring will continue with automated water level measurements and water quality sampling. The results of Phase II will be a data summary and interpretation, including an evaluation of the relationship between vegetation, soil, and infiltration, and an evaluation of the stability of the system at the ten-year monitoring period.

7.3.3 Phase III: Long Term Monitoring, Years Ten 10 through 30

Phase III will continue the inspection and maintenance activities of Phases I and II. Observed infiltration through the ET cover during Phase III should continue to be zero. Annual performance monitoring will continue with automated water level measurements and water quality sampling. The results of Phase III will be a data summary and interpretation, including an evaluation of the relationship between vegetation, soil, and infiltration and an evaluation of the stability of the system at the end of the 30-year monitoring period.

8. Constructibility Evaluation

The conceptual design of the Present Landfill cover provides for standard construction methods. The earthwork, aggregate placement, piping installation, geosynthetics installation, and revegetation associated with construction of the cover are all practices that are common in the U.S. construction industry. This constructibility evaluation examines all components of the design to ensure the cover can be properly built in an efficient and effective manner.

A key factor in the construction schedule and approach will be whether on-site or off-site soil borrow sources are selected. The construction methods and equipment will vary depending on whether on-site excavation is needed and on the means of soil transport, whether with on-site haul vehicles or trucks from off-site sources. Access routes and transportation plans to haul soil from off-site sources is a key constructibility issue if large soil quantities for the major cover components are imported. This section addresses several alternatives for on-site and off-site borrow soil sources

8.1 Material Sources

A variety of potential sources of soil and rock materials exist, including both off-site commercial quarries and on-site borrow areas at RFETS. Final material selections should provide sufficient material quantities and also help to attain RFETS environmental restoration objectives. Use of on-site materials can benefit the RFETS environmental restoration process in the following ways:

- Recontouring of an ET apron east of the Present Landfill will provide needed soil and rock while simultaneously addressing several technical environmental restoration challenges.
- Revegetation of the ET covers with native species will provide infiltration reduction, assurance of longevity, and compatibility with the surrounding environment.

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Final determinations of the suitability of on-site materials will require additional investigation and testing of these materials and design optimization to accommodate the properties of available materials within the ET cover design.

A detailed off-site borrow source investigation has been conducted and suitable soil located. Depending on the final design configuration, borrow materials may come from on-site, off-site, or a combination of on- and off-site sources.

8.1.1 Material Availability

On-site soils possess the appropriate characteristics for the ET cover soil-rooting medium and erosion protection layer. The Flatirons Series surficial soils and Rocky Flats Alluvium in the shallow subsurface contain loamy soils with a significant clay fraction, which provide good moisture retention characteristics. The on-site soil and alluvium also contains a large fraction of cobble-size rock, which can be used to reinforce the upper erosion protection layer.

Materials that may be obtained from off-site sources include synthetic materials used in the methane-venting system, seed mix, and possible soil amendments. Synthetic materials used in the Present Landfill gas-venting system will be obtained from commercial, off-site suppliers. The synthetic materials used in the gas-venting layer include:

- Geotextile separation fabric
- HDPE piping (perforated, solid, and fittings)
- Landfill gas vents (HDPE, steel, or other materials)

Because many commercial providers of these materials are available, the costs are reasonable and competitive, and will be a minor portion of the overall construction costs. The conceptual design for the gas-venting system includes materials with typical geotextile strength, pipe sizing, vent types, etc.

Seed mix and possible soil amendments will be procured from off-site sources based on seed specifications and soil nutrient needs. Seed mix specifications must meet KH Ecology Group

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requirements, with consideration of the seed species that can be reasonably obtained. Testing for soil nutrients should be conducted and decisions made regarding the value of adding soil nutrient amendments to improve revegetation efforts. Selection of soil amendments should be investigated more fully near the time of construction, because local availability of sludge, compost, and agricultural fertilizers can change rapidly depending on local government and industrial programs.

8.2 Geotechnical Site Investigation

A geotechnical site investigation of the proposed soil borrow source is needed to determine soil properties for final design. A series of soil borings will be needed across the borrow area, whether on-site or off-site, to obtain samples for laboratory testing and determine subsurface characteristics. This section describes general requirements for the geotechnical site investigation drilling program, with approximate numbers of soil borings, depths, and test requirements. Final plans for the geotechnical investigation will be made during the final design stage.

The geotechnical investigation described in this section focuses primarily on the Present Landfill ET apron soil borrow area, but may also be adapted to other areas at RFETS or to off-site borrow locations. If soil is obtained from an off-site commercial source where sufficient material testing has already been conducted, a geotechnical site investigation will not be required. In this case, detailed material specifications will be needed, in combination with appropriate conformance testing to demonstrate compliance with the specification.

The geotechnical site investigation at the on-site Present Landfill ET apron or other potential RFETS on-site soil borrow area will examine the following issues:

- Thickness of Rocky Flats Alluvium
- Depth to bedrock
- Depth to the water table
- Possible presence of soil or groundwater contaminants

The site investigation should be coupled with KH efforts to evaluate the groundwater intercept system at the Present Landfill.

Soil samples should be collected from the Rocky Flats Alluvium for laboratory testing of geotechnical and hydrologic properties. These tests are anticipated to include, at a minimum:

- Standard Proctor compaction
- Atterberg limits
- Grain-size distribution (sieve and hydrometer)
- Internal shear strength
- Cohesion
- Moisture retention characteristic curves
- Saturated hydraulic conductivity
- Dry bulk density
- Porosity
- Particle density
- In situ moisture content

Because cobbles too large to be included in conventional sampling by driven split-spoon samplers are present in RFETS soils, cobble percentages should be described and quantified by observation of drill cuttings. The size-range of cobbles, coupled with laboratory grain-size data, will be important in determining soil suitability for erosion protection. The importance of cobbles in the design will require a relatively large-diameter drill. Hollow-stem auger drilling will satisfy most requirements of this project, although other drilling methods may also be evaluated. Additional large-diameter borings or test excavations will be needed to adequately characterize the fraction of large rocks that cannot be sampled with a hollow-stem auger.

Soil borings should be drilled through the alluvium and into the uppermost portion of the underlying bedrock. Bedrock underlying the site consists of undifferentiated sandstone, siltstone, and claystone of the Arapahoe and Laramie formations (KH, 1996). During drilling, soil samples should be collected using split-spoon samplers at a minimum of 5-foot intervals. Material descriptions should be recorded by a qualified geologist and a Standard Penetration

Tests should be recorded along with sample collection data. Split-spoon sampling will confirm that the borings have fully penetrated the alluvium and that the uppermost bedrock has been reached.

All borings should be plugged and abandoned by fully grouting the borings from bottom to top. Grout should be emplaced by pumping it through a tremie pipe as the auger flights are removed. Grout should be injected until it reaches the surface, then topped off as necessary one or two days later. The grout may be a cement slurry with a bentonite amendment or a pure bentonite gel. Bentonite gel has the advantage of minimizing any affects on the borrow soils when they are excavated for cover construction.

A series of approximately 20 to 40 soil borings are expected to adequately characterize site conditions. Across the potential borrow area, the thickness of the alluvium is expected to range from approximately 5 to 30 feet in thickness. The site investigation will determine the depth to bedrock and allow accurate calculation of available borrow soil quantities.

The lower portion of the alluvium is saturated, and accurate water table elevation data will be gathered during the investigation. These data will be very important for final excavation plans and the design of dewatering systems for excavation, if needed. The water table elevation will also be an important design consideration for the design of a constructed ET apron. As needed, monitor wells or piezometers may be installed in soils to provide additional water level data or to collect water quality samples.

8.3 Construction Methods

Construction methods for each of the components in the ET cover conceptual design are straightforward and follow common industry practice. The majority of the construction effort will be earthwork to place the soil-rooting medium, erosion protection, and aggregate layers. The construction methods required for the Present Landfill ET cover are described in the following sections.

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8.3.1 *Clearing and Grubbing*

All areas where the cover will be placed and areas of excavation for soil borrow will be cleared and grubbed prior to starting earthwork. Existing vegetation should be stripped in order to provide consistent adhesion between the existing soils and the overlying soil materials place for cover construction. This is particularly important on the eastern slope of the Present Landfill, where steep slopes of approximately 30 percent currently exist. Clearing and grubbing this slope will avoid creating a potential slippage plane along a layer of matted vegetation. Likewise, vegetation should be stripped from the surface of soil borrow areas to provide consistent borrow soil and avoid irregular amounts of plant material mixed with the borrow soil.

A suitable means of disposal will need to be determined for the vegetation and soil generated by clearing and grubbing. The possibility of contaminants in the material may need to be considered and could affect disposal alternatives. At the Present Landfill, where organic solid wastes have been disposed, it appears suitable to place and compact the clearing and grubbing spoils on a portion of the landfill where additional fill may be useful to reach final design grades. The spoils will exhibit properties much like the rest of the solid waste mass in the landfill and will not affect the ET cover.

8.3.2 *Grade Control*

Control of construction grades is needed throughout the project using conventional surveying techniques. Grade control provides for proper placement of all materials used in construction and construction according to the final design plans. Independent survey verification should be used to spot-check grades and material thicknesses as a quality control measure. The grade control survey also provides as-built quantity determinations for payment to the construction contractor.

8.3.3 Soil Excavation

Soil excavation will be an important element only if an on-site borrow source such as the ET apron is selected. For off-site borrow sources, only very minor, if any, excavation will be needed in the course of tie-ins to existing ground surface.

If an on-site borrow source is selected, excavation may be accomplished using:

- Scrapers with direct haul to the placement location
- Track-hoe excavator(s) and haul trucks
- Farm-type tractors with scraper trailers

The contractor's choice of excavation equipment will depend on the proximity between the borrow source and placement location and on the geotechnical characteristics of the on-site soil. Ripping of the soil using bulldozer(s) may be needed if scrapers have difficulty excavating the material directly.

8.3.4 Soil and Aggregate Processing (optional)

On-site soil and aggregate processing can be set up to screen rock and aggregate materials for use in the erosion protection layer, landfill gas-venting layer, and ET apron flow distribution trenches. The on-site soils contain significant cobble and gravel percentages, and appear suitable for processing based on nearby commercial quarrying and processing of similar soils. On-site materials processing is common construction practice and can be effectively set-up for short-term operation. Soils processing is typically a more time consuming process than other aspects of the earthwork project; therefore, timeframes to process the necessary material quantities should be carefully considered in planning the critical timeline for the construction schedule.

8.3.5 Soil Transportation

Transportation of soil from off-site sources must address numerous environmental and public safety issues. The material quantities for this project are significant (Tables 6 and 7), and depending on the volume of off-site materials used, impacts from haul vehicle may be a critical issue. Based on the material quantities, transportation of the main cover construction materials will require many thousands of truckloads of material. Transportation on public highways will require appropriate approvals, which have not been included as part of this conceptual design project.

The haul distance from off-site quarries will have a significant impact on the construction cost, and costs are expected rise dramatically if transportation distances become excessive. Since the soil and rock materials needed for the bulk of construction will require fairly common characteristics, these materials should be available from nearby locations.

Two previous reports, (KH, 1996 and EG&G, 1994), provide additional information on transportation issues. The EG&G report evaluates borrow sources, including transportation over public highways and the locations of many of the commercial quarries operating in the area in 1994. If an off-site borrow location is used, the increase in daily truck traffic on the highways will have to be addressed as a public safety issue. The KH report, a decision document for the Present Landfill, addresses air quality impacts for a planned haul road across the northern part of RFETS leading directly to the LaFarge Quarry. This report identified a 2.5-mile haul road to the LaFarge Quarry as a feasible option for the import of soils.

8.3.6 Soil Placement

The ET cover will be constructed in a manner that limits compaction, which will require the careful selection of placement equipment and establishment of haul routes. This is important for the establishment of vegetation, which requires specified densities to permit optimum root growth and maximize water-holding capacity. Soil compaction will be limited to approximately 80 to 90 percent of Standard Proctor density. Compaction of soils will not be needed as with typical earthwork, and this will provide savings in construction cost and speed progress.

Undoubtedly, excessive compaction of certain portions of the construction site will occur as a result of temporary haul roads and vehicle traffic. As needed, any over-compacted areas will be ripped and loosened as the final soil preparation.

Minimal soil compaction can be achieved by the use of tracked or low-weight wheeled vehicles in combination with the placement of thick lifts of two feet or more. Where weight restrictions are important, such as public roadway crossings, farm-type tractors may be used to haul and place soil using scraper trailers; usually with a set of two or three linked scrapers. The use of low wheel-weight vehicles may be advantageous as it will keep the need for final ripping to a minimum.

The degree to which soil compaction occurs during placement will depend largely on the moisture content of the material. Soils observed at the nearby LaFarge Quarry are relatively moist in the shallow and deep soil profile. Based on these limited observations, RFETS soils appear to be in the range of optimum moisture, which indicates they will tend to compact significantly during routine construction. Specifying and controlling soil moisture during construction can limit the degree of compaction, but only if soil moisture is significantly drier than optimum. Importing drier or processed soils may be an option to meet specifications. As a practical consideration, drying of soils in the quantities needed may be difficult to achieve or control. However, a combination of construction methods to limit soil compaction and final ripping and processing as needed to loosen the soil, will be capable of meeting the soil density specifications.

8.3.7 Gas-Venting Aggregate Layer Placement

The gas-venting aggregate will be clean gravel, free of fines to provide good air-flow permeability. The aggregate will be a processed, screened material either imported from an off-site commercial source or processed on-site. Sieving is adequate, since the presence of some fines will not significantly change air permeability. Placement and spreading of the material will follow standard earthwork practices. The gentle slopes of less than 14 percent will not present any difficulty for constructibility of the aggregate layer.

8.3.8 Piping Installation

Piping installation for the passive landfill gas-venting system will generally follow standard industry practices for installation of landfill gas collection system piping for active landfill extraction systems. The design requirements and construction methods for these systems are well understood from numerous applications across the U.S. Various piping materials and installation methods may be used, but the most common for landfill gas collection applications is welded HDPE pipe. Field fusion of the HDPE pipe should be conducted by qualified personnel and should meet specified QC and testing requirements.

Final design of the piping system may take various approaches with constructibility issues in mind. The most practical construction approach envisioned for the conceptual design is the excavation of shallow trenches (approximately 1 foot by 1 foot) into the prepared subgrade soil below the cover. The piping can be installed within these trenches with underlying and overlying gas-venting aggregate as a bedding material. The remaining gas-venting aggregate layer can then be constructed above the bedded piping network.

8.3.9 Geotextile Separation Fabric Installation

A geotextile separation fabric will be installed above the landfill gas-venting aggregate layer to prevent intrusion of fines from the overlying soil-rooting medium. Use of geotextiles for this type of application is common and is very similar to the standard installation of geotextile separation fabric over the drainage aggregate in a landfill liner system. The geotextile is deployed in rolls and the individual panels are seamed together using portable stitching equipment. A 10-to 12-ounce nonwoven geotextile is commonly employed. Final design requirements will need to consider geotextile thickness and strength requirements based on specific soil properties and potential slope and settlement stresses.

8.3.10 ET Apron Flow Distribution Trenches (optional)

Final design and constructibility issues for flow distribution trenches will need to be addressed if the optional ET apron is implemented. In principle, construction of these trenches will be reasonably practical and simple. Installation of gravel-filled trenches is anticipated to depths of up to 5 to 10 feet. A track-hoe excavator with a bucket width of approximately 2 to 3 feet will most likely be used for trenching.

Trenches may encounter saturated conditions in the vicinity of the seep at the eastern toe of the landfill. The excavation of the ET apron may be near the water table, and trenches may extend into the shallow groundwater. Trenches may need to be stabilized if excessive sloughing of soils occurs. However, it is anticipated that trenches may be excavated relatively easily to the planned depths, including excavation of up to about 5 feet into saturated materials.

Currently, a treatment system is operating at the location of the seep at the eastern toe of the landfill. Construction of the ET cover will extend over this area, and the existing treatment system will need to be removed. The ET apron is one option for elimination of the seep, but other treatment methods may also be selected. Suitable plans will need to be developed to transition from the current treatment system to the new system. The ET cover can provide for this transition because part or all of the ET apron trenches can be constructed while the existing treatment system continues to operate. The existing treatment system can then be shut down to begin to allow passive flow of seepage into the ET apron. Other interim measures to provide dewatering or treatment of the seep can be developed, if necessary.

Trenches will be backfilled with gravel to create permeable conduits to distribute seep water in the shallow soils, where the water is available for uptake by vegetation for enhanced ET. Screened on-site gravel may be suitable for this application. The trenches may be only partially filled with gravel, with placement of a choking layer soil of specified gradation over the gravel to prevent entry of fine-grained soil particles from above. Two to three feet of soil suitable as a rooting medium will be placed in the upper portion of the trench to maintain the continuity of the ET apron vegetation.

8.3.11 Revegetation

Revegetation plans must meet KH Ecology Group requirements, but should also follow fairly standard practices for seed application and mulching. Either drill seeding or hydro-seeding may be used without difficulty on gentle slopes that are readily accessible. Mulching and crimping may be used, as needed, to temporarily stabilize the soil surface until plants germinate and become established.

Soil amendments, if needed to provide added nutrients and organic matter, will be tilled into the soil at specified depths as soil placement occurs. The soil used for the erosion protection layer may be a processed material, with rock and gravel added for erosion resistance. Soil amendments could be added to this topsoil during processing, either by mixing and tilling the soil or other methods.

8.3.12 Construction Methods Summary

Proposed construction methods for the ET cover follow standard industry standards for general earthwork projects. The construction methods are straightforward and uncomplicated, and there are many qualified and competitive contractors capable of performing this work. The only unique element of construction is the requirement for low compaction, which can be readily handled with low ground pressure (lgp) construction equipment and careful haul route planning.

8.4 Project Implementation and Construction Schedule

This section presents a preliminary schedule (Figure 14) for ET cover construction and full implementation of the design and construction project. The schedule includes final engineering design and construction, but does not include the current review and approval process. This is because the approval process is linked to many other issues and decisions in the in the overall context of Present Landfill final closure and site-wide RFETS closure plans.

The schedule assumes the selection of a reasonably close soil borrow site; either on-site or within a short haul distance where soil can be provided to the project at the quantities desired for an efficient construction sequence. To place 5,000 cy of soil per day requires approximately 200 truckloads of soil from an off-site borrow source. This is approximately the quantity of soil that might be excavated on-site with six to eight scrapers, or with one or two excavators and six to eight haul trucks.

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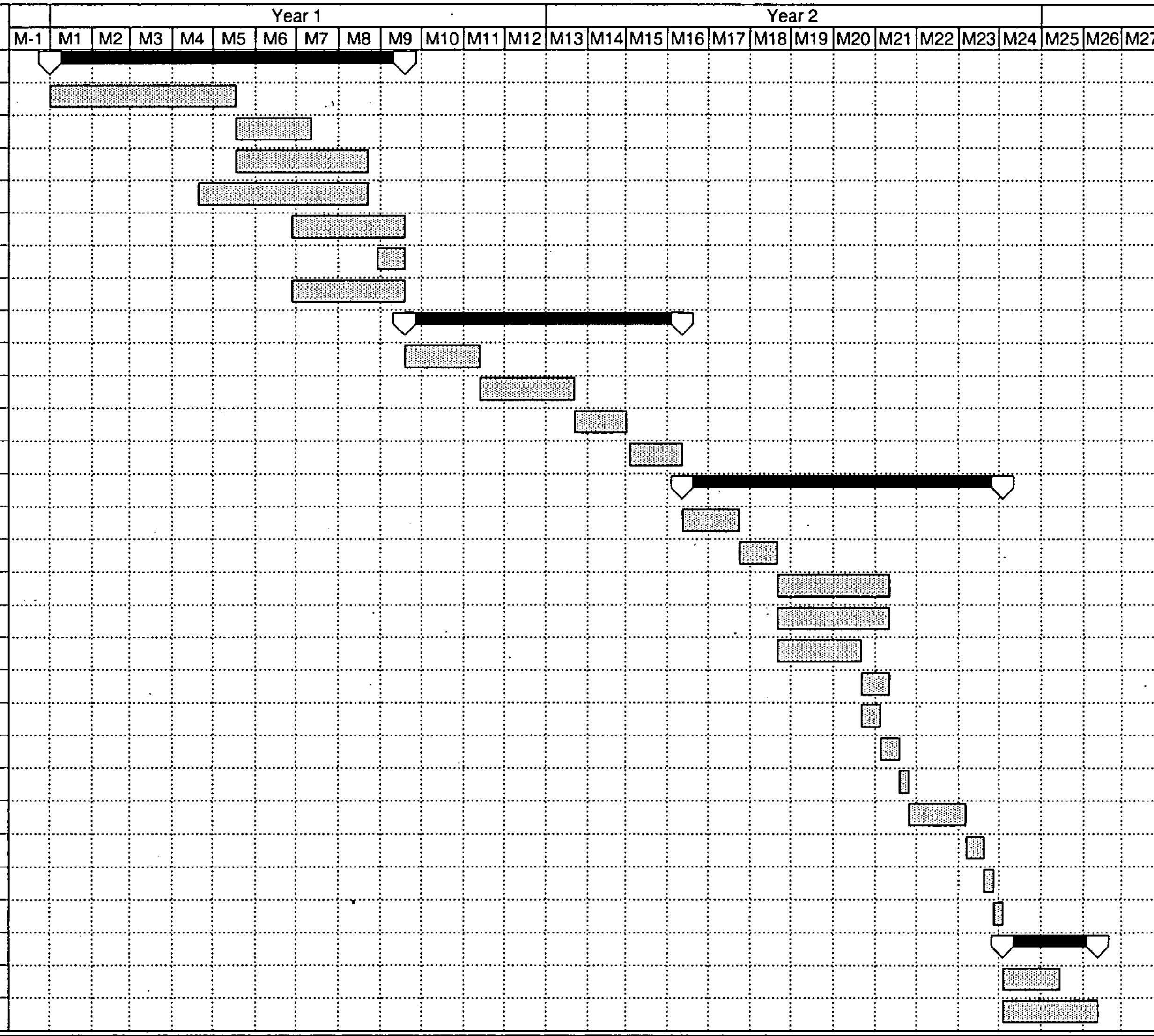
Figure 14 - Preliminary Project Schedule
Final Design and Construction of ET Cover for the Present Landfill
Rocky Flats Environmental Technology Site

WBS	Task Name
1	**Final Engineering Design**
1.1	Geotechnical Investigation and Materials Testing
1.2	Cover Performance Modeling
1.3	Design Calculations/Review and Approval
1.4	Design Drawings/Review and Approval
1.5	Construction Specifications
1.6	Construction Cost Estimate
1.7	Contract Documents/Review and Approval
2	**Bid Administration**
2.1	Solicit Construction Bids/Prequalification
2.2	Contractor Bid Preparation
2.3	Select Contractor
2.4	Negotiate/Sign Contract
3	**Construction**
3.1	Contractor Lead Time
3.2	Site Preparation/Clear and Grub
3.3	ET Apron Excavation (optional)
3.4	Rock and Gravel Processing (optional)
3.5	Subgrade Soil Placement
3.6	ET Apron Gravel Trenches
3.7	Gas-Venting Layer Gravel
3.8	Gas-Venting Piping
3.9	Geotextile Separation Fabric
3.10	Soil Rooting Medium
3.11	Erosion Protection Layer
3.12	Seeding/Revegetation
3.13	Site Clean-Up
4	**Construction Certification**
4.1	Engineer's Certification Report
4.2	As-Built Drawings



Project: rocky flats
Date: Fri 12/21/01

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split | External Tasks | Project Summary | External Milestone | Deadline

The implementation schedule, which is typical for landfill cover construction projects, provides for the primary earthwork for the soil-rooting medium and erosion protection layer to be conducted over a timeframe of approximately three to four months. Construction could proceed at a slower pace, but still be conducted efficiently, if hauling rates from off-site material sources are limited or if less equipment is used for on-site excavation and construction.

The complete construction timeframe is expected to take eight to ten months to complete. This schedule is reasonable for the proposed work and material quantities required for the Present Landfill ET cover construction, and includes a buffer for delays due to adverse weather conditions. Over the course of a year-long construction project, a significant number of weather shut-down days must be planned. The construction schedule could probably be compressed by one to two months, if an aggressive schedule is taken for construction activities and the required equipment is mobilized to the site. Any on-site processing of soils to generate gravel and rock materials may require significant timelines; therefore, soil quantities and screening capabilities should be considered carefully in the schedule.

With the exception of post-closure monitoring, the entire project could be completed in approximately 18 to 24 months. This schedule is ample for the engineering design, construction administration, construction, and as-built final certification for typical landfill cover projects. The scheduling timeframes for RFETS are uncertain, and the project success and schedule may hinge on issues that are unforeseen at this point. The schedule provided is based on unimpeded design and construction progress after all regulatory approval processes are complete.

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9. Cost Estimate

A project cost estimate has been prepared for final design and construction of the Present Landfill ET cover. The cost estimate is a preliminary projection based on the ET cover conceptual design as presented in this report. The cost estimate is intended to provide preliminary budgetary planning information to assist RFETS decisions on whether to implement the ET cover approach. Construction cost estimates are provided for each of the two cover options for the Present Landfill; either covering the asbestos disposal areas in-place or relocating the asbestos. The estimates are broken down by construction costs, engineering, costs, and operations and maintenance (O&M) costs, as shown in Tables 10 and 11).

Included in the project cost estimate are direct construction costs as well as the full costs for final engineering design, contractor selection, construction administration, construction inspection, and quality control testing. The cost estimate assumes on-site soils are used and processed. The costs were based on typical industry standards for landfill design and construction. Construction contracting must follow Federal acquisition regulations and KH contracting procedures. The project cost estimate does not consider permitting and regulatory approval processes, which could require a significant effort for the RFETS Present Landfill. Because the requirements for regulatory processes at RFETS are beyond those included in typical engineering practice for cost estimating, this aspect of the cost estimate should be considered in more detail by KH.

9.1 Engineering

The project cost estimate includes direct engineering costs for final design, construction administration, and construction inspection and testing. The engineering costs are based on typical percentages of the total construction costs. The engineering costs are for design only and do not include permitting efforts that will be required prior to proceeding with the final design. The engineering costs include the geotechnical investigation needed for selection of soil borrow sources. Each aspect of the engineering costs is described in this section.

Table 10. Conceptual Cost Estimate ET Cover
Present Landfill, Cover Asbestos In Place Option
Page 1 of 3

Item	Unit	Unit Price ($ [a])	Quantity	Total Price ($)	Comments
Construction Costs					
Mobilization/demobilization	LS	262,656	1	262,656	Three percent of construction cost
Construction staking	AC	1,000	42.8	42,800	Total disturbed area
Clear and grub construction areas	AC	1,750	42.8	74,900	With dozer, dispose at Present Landfill
Excavation	CY	3.10	199,162	617,402	With scrapers
Soil processing/screening	CY	2.50	160,965	402,413	Screen/process on-site
Soil transportation, on-site	CY	3.15	360,127	1,134,400	Load, 0.5-mile RT haul, from excavation & processing
Erosion protection layer	CY	1.43	50,870	72,744	Place with dozer
Soil-rooting medium - on-site	CY	1.43	127,831	182,798	Place with dozer
Soil-rooting medium - off-site	CY	23.67	247,510	5,858,562	Purchase material, 10-mile RT haul, place with dozer
Excavate - ET apron trenches	CY	3.33	3,970	13,220	With track-mounted excavator
Gravel - ET apron trenches	CY	4.02	3,970	15,959	Place with loader
Gravel - gas venting layer	CY	1.43	16,491	23,582	Place with dozer
HDPE perforated pipe - 2" diameter	LF	6.00	10,000	60,000	
HDPE pipe - 4" diameter	LF	7.50	4,675	35,063	
Revegetation	AC	4,700	47.1	221,370	Native seed mix plus fertilizer (actual cost from RMA)
			Subtotal	**9,017,869**	
Engineering Costs					
Design survey	LS	45,000	1	45,000	Percentage of total construction cost
Design geotechnical investigation	LS	81,000	1	81,000	Drilling, laboratory testing, and report
Engineering design:					
Design drawings	%	2.25	1	202,902	Percentage of total construction cost
Plans and specifications	%	4.00	1	360,715	Percentage of total construction cost
Bidding/contract documents	%	1.00	1	90,179	Percentage of total construction cost

[a] Some items, as noted, are estimated as a percentage of the total construction cost.

LS = Lump sum
AC = Acre
CY = Cubic yards
RT = Round trip
ET = Evapotranspiration
HDPE = High-density polyethylene
LF = Linear feet
RMA = Rocky Mountain Arsenal
CWA = Clean Water Act
QA = Quality assurance
YR = Year
EA = Each
HR = Hour

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Table 10. Conceptual Cost Estimate ET Cover
Present Landfill, Cover Asbestos In Place Option

Item	Unit	Unit Price ($ [a])	Quantity	Total Price ($)	Comments
Engineering Costs (continued)					
CWA 402/404 permitting/monitoring	LS	35,000	1	35,000	Percentage of total construction cost
Construction administration	%	1.50	1	135,268	Percentage of total construction cost
Construction QA inspection	%	2.00	1	180,357	Percentage of total construction cost
Record drawings	LS	16,000	1	16,000	
			Subtotal	**1,146,421**	
			Construction Project Total	**10,164,290**	
Operation and Maintenance Costs					
Erosion maintenance (year 1)	YR	63,171	1	63,171	Regrade and revegetate 10 percent of total cover area first year
Erosion maintenance (years 2 to 6)	YR	31,585	5	157,926	Regrade and revegetate 5 percent of total cover area years 2 to 6
Inspection	YR	5,000	30	150,000	Annual inspections for 30 years
Remove gas venting riser pipes	EA	125	44	5,500	Remove risers after methane gas levels have decreased
Equipment (monitoring 30 years):					
Campbell 23X datalogger	EA	2,800	3	8,400	
Enclosures	EA	350	3	1,050	
AM416 multiplexes	EA	575	3	1,725	
CE 8 excitation panel	EA	250	3	750	
Solar panel	EA	495	3	1,485	
Miscellaneous connectors	EA	200	3	600	
Gas tubing	EA	2,000	1	2,000	
Gas monitor/logger	EA	6,500	3	19,500	
Computer and data telemetry	EA	6,500	3	19,500	
Storage modules	EA	610	3	1,830	
Tipping bucket rain gauge	EA	380	1	380	

[a]Some items, as noted, are estimated as a percentage of the total construction cost.

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YR = Year
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HR = Hour

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Table 10. Conceptual Cost Estimate ET Cover Present Landfill, Cover Asbestos In Place Option Page 3 of 3

Item	Unit	Unit Price ($[a])	Quantity	Total Price ($)	Comments
Operation and Maintenance Costs (continued)					
Barometric pressure sensor	EA	350	1	350	
Heat dissipation sensors	EA	450	24	10,800	
Moisture probes	EA	261	6	1,566	
Labor and recurring costs:					
Set up and programming (technician)	HR	65	16	1,040	
Set up and programming (manager)	HR	110	80	8,800	
Travel, installation, training RFETs staff	HR	110	80	8,800	
Travel expenses	LS	2,000	1	2,000	
Biannual equipment evaluation	HR	110	160	17,600	Two times per year for six years
Biannual expenses	LS	15,000	1	15,000	
Soil water chemistry	YR	8,000	6	48,000	Annual testing for 6 years
Reporting and data analysis:					
Annual reports, quarterly review	YR	12,000	6	72,000	Biweekly data review, quarterly updates, annual reports
Final report and recommendations	LS	38,000	1	38,000	
			Subtotal	**657,773**	
Construction Costs				9,017,869	
Engineering Costs				1,146,421	
Operation and Maintenance Costs				657,773	
			Total	**10,822,063**	

[a]Some items, as noted, are estimated as a percentage of the total construction cost.

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QA = Quality assurance
YR = Year
EA = Each
HR = Hour

Table 11. Conceptual Cost Estimate ET Cover
Present Landfill, Relocate Asbestos Option

Item	Unit	Unit Price ($[a])	Quantity	Total Price ($)	Comments
Construction Costs					
Mobilization/demobilization	LS	289,016	1	289,016	Three percent of construction cost
Construction staking	AC	1,000	41.25	41,250	Total disturbed area
Clear and grub construction areas	AC	1,750	41.25	72,188	With dozer
Strip and stockpile	CY	3.11	18,187	56,562	Strip upper 12" in cut area, haul 1,500' and stockpile
Excavation	CY	3.10	251,715	780,317	Scrapers - includes load and haul
Soil processing/screening	CY	2.50	175,982	439,954	Screen/process on-site
Soil transportation, on-site	CY	3.15	427,697	1,347,245	Load, 0.5-mile RT haul, from excavation and processing
Erosion protection layer	CY	1.43	42,665	61,011	Place with dozer
Soil rooting medium - on-site	CY	1.43	169,459	242,326	Place with dozer
Excavate - ET apron trenches	CY	3.33	3,970	13,220	With track-mounted excavator
Gravel - ET apron trenches	CY	4.02	3,970	15,959	Place with loader
Gravel - gas venting layer	CY	1.43	12,738	18,215	Place with dozer
HDPE perforated pipe - 2" diameter	LF	6.00	8,000	48,000	
HDPE pipe - 4" diameter	LF	7.50	3,911	29,333	
Regrading solid waste (option)	CY	1.75	32,800	57,400	Regrade with dozer to reduce cover height
Relocate asbestos	CY	500	12,395	6,197,500	Unit price provided by Kaiser-Hill
Revegetation	AC	4,700	45.4	213,380	Native seed mix plus fertilizer (actual cost from RMA)
			Subtotal	**9,922,876**	
Engineering Costs					
Design survey	LS	45,000	1	45,000	Percentage of total construction cost
Design geotechnical investigation	LS	81,000	1	81,000	Drilling, laboratory testing, and report

[a]Some items, as noted, are estimated as a percentage of the total construction cost.

LS = Lump sum
AC = Acre
CY = Cubic yards

RT = Round trip
ET = Evapotranspiration
HDPE = High-density polyethylene

LF = Linear feet
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Table 11. Conceptual Cost Estimate ET Cover
Present Landfill, Relocate Asbestos Option

Item	Unit	Unit Price ($[a])	Quantity	Total Price ($)	Comments
Engineering Costs (continued)					
Engineering design:					
Design drawings	%	2.25	1	223,265	Percentage of total construction cost
Plans and specifications	%	4.00	1	396,915	Percentage of total construction cost
Bidding/contract documents	%	1.00	1	99,229	Percentage of total construction cost
CWA 402/404 permitting/monitoring	LS	35,000	1	35,000	Percentage of total construction cost
Construction administration	%	1.5	1	148,843	Percentage of total construction cost
Construction QA inspection	%	2.00	1	198,458	Percentage of total construction cost
Record drawings	LS	16,000	1	16,000	
			Subtotal	**1,243,709**	
			Construction Project Total	**11,166,585**	
Operation & Maintenance Costs					
Erosion maintenance (year 1)	YR	60,890	1	60,890	Regrade and revegetate 10% of total cover area first year
Erosion maintenance (years 2 to 6)	YR	30,445	5	152,226	Regrade and revegetate 5% of total cover area years 2 to 6
Inspection	YR	5,000	30	150,000	Annual inspections for 30 years
Remove gas venting riser pipes	EA	125	37	4,625	Remove risers after methane gas levels have decreased
Equipment (monitoring 30 years):					
Campbell 23X datalogger	EA	2,800	3	8,400	
Enclosures	EA	350	3	1,050	
AM416 multiplexes	EA	575	3	1,725	
CE 8 excitation panel	EA	250	3	750	
Solar panel	EA	495	3	1,485	
Miscellaneous connectors	EA	200	3	600	
Gas tubing	EA	2,000	1	2,000	

[a]Some items, as noted, are estimated as a percentage of the total construction cost.

LS = Lump sum
AC = Acre
CY = Cubic yards
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Table 11. Conceptual Cost Estimate ET Cover Present Landfill, Relocate Asbestos Option

Item	Unit	Unit Price ($ [a])	Quantity	Total Price ($)	Comments
Operation & Maintenance Costs (continued)					
Gas monitor/logger	EA	6,500	3	19,500	
Computer and data telemetry	EA	6,500	3	19,500	
Storage modules	EA	610	3	1,830	
Tipping bucket rain gauge	EA	380	1	380	
Barometric pressure sensor	EA	350	1	350	
Heat dissipation sensors	EA	450	24	10,800	
Moisture probes	EA	261	6	1,566	
Labor and recurring costs:					
Set up and programming (technician)	HR	65	16	1,040	
Set up and programming (manager)	HR	110	80	8,800	
Travel, installation, training RFETS staff	HR	110	80	8,800	
Travel expenses	LS	2,000	1	2,000	
Biannual equipment evaluation	HR	110	160	17,600	Two times per year for six years
Biannual expenses	LS	15,000	1	15,000	
Soil water chemistry	YR	8,000	6	48,000	Annual testing for 6 years
Reporting and data analysis:					
Annual reports, quarterly review	YR	12,000	6	72,000	Biweekly data review, quarterly updates, annual reports
Final report and recommendations	LS	38,000	1	38,000	
			Subtotal	**648,918**	
Construction costs				9,922,876	
Engineering costs				1,243,709	
Operation and maintenance costs				648,918	
			Total	**11,815,503**	

[a]Some items, as noted, are estimated as a percentage of the total construction cost.

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9.1.1 Final Engineering Design

Engineering design will begin with the initial activities that must be completed to provide the basis for remaining design activities. The initial engineering work will include:

- Design survey for current topography
- Geotechnical investigation of soil borrow materials

The design survey is needed to provide an update to the existing topographic survey to account for changes that are expected to occur. At the Present Landfill, continuing waste settlement may significantly change the existing grades over a few years between the survey and preparation of final design drawings. The updated survey is needed to account for these changes in the final design, particularly as these changes affect material quantities.

The geotechnical investigation follows the recommended investigation described in Section 8.2. The geotechnical investigation cost estimate includes not only engineering costs, but also the full costs for drilling and soils laboratory analyses.

The primary engineering effort is to complete construction plans and specifications for ET cover construction. These efforts will include:

- Design calculations
- Design drawings (grading plans and details)
- Construction specifications (materials and methods)
- Engineer's construction cost estimate

These engineering work products will be incorporated in final construction documents suitable to complete construction.

9.1.2 *Construction Administration*

The engineer will provide periodic oversight of construction progress to verify that construction is completed according to plans. Construction administration will include the following activities:

- Provide design plan clarification and interpretation
- Review and approve submitted shop drawings
- Provide field orders to address questions and direct the work
- Conduct regular project progress meetings
- Provide KH with written and verbal presentations of work complete, schedule, and expenditures
- Complete final inspection
- Prepare record drawings based on contractor mark-ups and recorded field conditions

The engineer's construction administration activities are typical of landfill construction projects, but will be adjusted as needed with associated cost changes, based on KH requirements and the assistance needed.

9.1.3 *Inspection and Testing*

CQA inspections will be conducted to ensure that the cover is constructed in accordance with the design. The CQA inspector will be responsible for materials testing, including field testing of soil densities, and collection of soil and synthetic materials for laboratory testing. Samples will be submitted to independent, certified materials testing laboratories to complete all required tests. The CQA inspector will be responsible to:

- Assure construction materials and procedures meet project specifications
- Observe material placement and installation procedures
- Review all field and laboratory tests for compliance with project specifications
- Prepare daily observation reports
- Prepare a final cover construction certification report

The cost estimate includes all costs for on-site inspection personnel and laboratory testing.

9.2 Construction

Construction costs are itemized based on unit costs and quantities of each material. Unit costs were obtained from the following sources:

- RSMeans® Heavy Construction Cost Data, 16th Annual Edition, 2002
- Inquiries with construction contractors regarding current, local prices
- DBS&A's in-house information and experience with similar landfill construction competitive bids
- RFETS recommended costs based on past projects

The construction cost estimate is based on the use of on-site soils from construction of the ET apron as the primary source of cover earthwork materials. The cost estimate relies on the previous borrow source evaluation for sufficient consideration of potential off-site material sources, suppliers, and transportation costs. The on-site soils appear suitable to provide any of the earthwork components needed for construction of the ET cover, although some of the cover components will require processing. Piping and geotextiles for the methane-venting system will be the only synthetic materials required.

The cost estimate considers on-site excavation, soil placement, regrading, and revegetation. Processing costs to screen on-site soils to generate rock and gravel materials are also included. The use of on-site soil for regrading (in on-site earthwork for site closure) will require a determination regarding the applicability of royalty payments. The status of mineral rights and possible royalty costs has not been investigated as part of the conceptual design.

On-site and nearby soils at RFETS or off-site commercial quarries appear suitable based on initial laboratory testing and modeling results. Numerous factors must be considered in selecting the final soil borrow source, and final recommendations are not part the conceptual design. Final decisions on the soil borrow source location will be made after material specifications are developed and more extensive soil testing is completed. As recommended in the 1994 borrow source evaluation (EG&G, 1994), competitive bids should be solicited either for off-site purchase and transportation or on-site excavation and regrading to obtain the most favorable terms. Whatever final borrow source is selected, suitable soils are available within reasonable haul distances to keep construction costs to a minimum.

9.3 Operation and Maintenance

Operation of the ET cover involves on-going performance monitoring as described in Section 7. Maintenance of the ET cover involves repair of erosion and revegetation, which may be needed over a limited timeframe until vegetation is well established to prevent erosion. In the long-term, both monitoring operations and maintenance needs will decline, and associated activities will be phased out. In this preliminary cost estimate for conceptual design, future costs have not been adjusted for present worth.

Operations include the installation of monitoring instrumentation and monitoring activities expected to be conducted for a minimum of six years, until vegetation is fully established and the performance of the ET cover can be demonstrated. The cost estimate provides details of the capital costs for monitoring system equipment and installation and recurring cost for operation, analysis, and reporting of the monitoring data and results.

Maintenance of the cover vegetation and possible erosion repair may be necessary over a period of approximately five years after cover construction until vegetation is well established. During the period of time it takes to establish the vegetation, some maintenance may be required; although in the long-term, cover erosion should be minor and longevity design objectives should be met. A maintenance budget is provided in the cost estimate to provide for minor reseeding and earthwork to repair erosion rills, if needed.

Periodic maintenance of the gas vents may be needed during the operational life of the gas-venting system. When gas generation rates have declined to a level at which the venting system is no longer needed, after approximately 25 to 75 years, the gas vents can be removed. Vent standpipes can be cut off and plugged below grade, with the remainder of the piping network left in place. The former gas vent locations can be allowed to revegetate naturally and effectively merge with the ET cover vegetation.

9.4 Cost Summary

The project cost for engineering and construction of the Present Landfill ET cover is estimated to be approximately $10.2 to 11.2 million. In addition, long-term monitoring and maintenance is expected to cost approximately $650,000. These costs are intended to provide preliminary budgetary planning information to assist RFETS decisions on implementing the ET cover approach.

A key issue affecting the Present Landfill ET cover construction cost estimate is the possible relocation of the asbestos disposal areas. Based on asbestos-handling unit costs provided by KH, the asbestos relocation will be the most significant cost component of the overall construction cost, accounting for more than 60 percent of the total construction cost. The cost for asbestos relocation hinges on very incomplete records of the quantity and location of asbestos materials. Additional research using available records and/or knowledge of RFETS personnel and possible site investigation, may help to better establish the history of asbestos disposal at the Present Landfill and determine the cost-effectiveness of either covering the asbestos in-place or relocating the asbestos to achieve a reduced final cover area.

The cost estimate is heavily dependent on the final soil borrow source selected. Off-site soil, imported to the site, will be much more costly than on-site soils. Transportation costs escalate substantially as the haul distance increases, and if off-site soils are imported, the source selected and haul distance will an important factor affecting total project costs. On-site and nearby soils at RFETS or off-site commercial quarries appear suitable for ET cover construction based on initial laboratory testing and modeling results. However, the cost estimate does not include a determination of the status of mineral rights and possible royalty costs for use of on-site soils. Final decisions on the soil borrow source location will be made after material specifications are developed and more extensive soil testing is completed. Whatever final borrow source is selected, suitable soils are available within reasonable haul distances to keep construction costs to a minimum.

10. Summary and Recommendations

The Present Landfill ET cover is being considered because of the cover's advantages in terms of performance, longevity, and compatibility with RFETS closure objectives and final land use plans. The conceptual design has evaluated the fundamental design features for the ET cover, and shows that the cover can meet the design criteria requirements. The ET cover is practical, constructible, and affordable, and has many advantages over conventional cover designs. The conceptual design is intended to provide sufficient design and performance information for a decision on whether to include an ET cover as a component of the final decision document for Present Landfill closure.

ET covers are a relatively young and innovative technology, yet the available data indicate the successful performance of ET covers continues to grow. In semi-arid climates in the western U.S., ET covers use the natural processes of soil moisture storage and plant uptake of moisture to provide infiltration reduction performance. For this project, a performance modeling demonstration of the proposed ET cover was completed to provide technical justification of the design approach and support ET cover feasibility.

This Conceptual Design Report considers the design and performance of an ET cover for the Present Landfill; other aspects related to final closure of the Present Landfill are being pursued under parallel projects. ET cover feasibility must be considered in conjunction with these other aspects of Present Landfill final closure plans, which include groundwater control, surface water quality, air emissions, wetlands preservation, and restoration of vegetation.

10.1 Meeting Project Goals

The ET cover modeling and conceptual design project has developed feasible solutions to meet multiple project goals. The ET cover design can provide an equivalent final cover for the Present Landfill that exceeds the performance of conventional regulatory designs and meets the unique longevity requirements for the RFETS application. The project goals stated in Section 1 of this Conceptual Design Report are met in the following manner:

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- Minimize surface infiltration through the cover to levels that equal or outperform standard regulatory designs.

  Performance modeling of the ET cover design using UNSAT-H shows that infiltration reduction performance is equivalent to standard designs that use FMLs and compacted clay. Modeling runs show that infiltration through the ET cover will be near zero.

- Achieve general regulatory compliance.

  The ET cover achieves regulatory compliance with Attachment 10 RFCA (CDPHE, 1996) by minimizing infiltration to the extent that contamination will not be spread. Further, the optional ET apron is a feasible solution to achieve compliance with groundwater and surface water quality requirements of RFCA Attachment 10, by using enhanced ET to contain, treat, and eliminate seepage.

- Meet data quality objectives.

  Data quality objectives presented in the project Work Plan (DBS&A, 2001b) have been met in the modeling and design processes, including review of the model selection and approach. The data quality objectives will continue to be implemented as decision processes move ahead.

- Design the best cover for site-specific climate, soils, and vegetation.

  The ET cover design fits the native conditions at RFETS. It plans for use of on-site soils or similar, nearby soils, and revegetation with sustainable, native species. The ET cover is well-suited to meet the long-term land use plan for grassland open space.

- Integrate the design with the overall RFETS closure configuration.

  The preliminary ET cover design provides gently sloping terrain similar to stable native slopes observed on-site.

- Sustain vegetation and minimize erosion.

  The ET cover will use soil with sufficient moisture storage capabilities to promote vegetation. Native soil profiles observed on-site show stable development and deep-rooted vegetation. The ET cover will minimize storm water runoff and erosion by allowing infiltration into the topsoil at the ground surface, which will sustain vegetation and thereby further minimize erosion.

- Maximize design life with minimum long-term care.

  The ET cover conceptual design relies on long-lasting earthen materials to maximize design life and eliminates synthetic materials that will degrade over time. Once vegetation is established to minimize erosion, long-term care will be minimal.

- Design in a manner that benefits surface water, groundwater, and air quality objectives.

  The ET cover design, and particularly the ET apron, provides benefits for surface water and groundwater quality by controlling and containing seepage through enhanced ET. Air quality objectives can be met by monitoring the methane-venting system for emission rates and providing active landfill gas control if needed.

- Protect wetlands and endangered species habitat.

  The ET cover is designed to minimize the area impacted by cover construction to minimize disturbance of wetlands and endangered species habitat. The ET cover will blend into the natural RFETS environment.

- Ensure design is soundly engineered, constructible, and cost-effective.

  The conceptual engineering design employs conventional construction methods and materials, and cost-effective approaches such as the use of on-site or nearby soil as the primary material. Specific construction methods needed to limit soil compaction for improved root growth in the ET covers are somewhat atypical, but not difficult to implement.

- Support RFETS environmental restoration objectives for site closure

The ET cover meets RFETS environmental restoration objectives for site closure, which include compliance with regulatory requirements for environmental protection, and the fulfillment of objectives including rapid implementation and cost-effective construction.

10.2 ET Cover Performance Modeling

Results of the cover performance modeling using UNSAT-H indicate that the ET cover is capable of achieving upward flux or no flux during periods of above-average precipitation. A comparison of percolation rates through the ET and conventional covers indicates that the rates in the ET cover are approximately the same as those in the conventional cover.

The modeling analysis demonstrated the following:

- Performance of the proposed 2-foot-thick ET cover is equivalent to a conventional FML/clay composite cover.
- Percolation for the ET covers is essentially zero.
- Local soil is available and suitable for the proposed ET cover system.
- Native vegetation will be suitable for the proposed ET covers.

These results are consistent with nearby research experience at RMA and support the conclusion that the potential for water percolation at the site is low.

10.3 ET Cover Monitoring Plans

The growing acceptance of alternative soil covers and review of performance test results supports a recommendation that field deployment of the ET cover be pursued at the Present Landfill. Implementation of the ET cover is supported by performance modeling analyses and research test plot results from similar sites. Information and data from the growing body of knowledge on alternative cover performance are sufficient to support the decision to proceed with final design and construction of an ET cover.

Monitoring of actual cover performance after deployment will verify whether the ET cover performs as expected. Data collected from sites in Colorado and other western states indicate that an alternative cover will perform well at RFETS. Actual cover performance is inherently more meaningful and useful than test plot data, particularly for the Present Landfill, where landfill gas venting is an integral component of the cover design. To verify that on-site performance at the Present Landfill is satisfactory, monitoring of the constructed alternative cover is recommended.

10.4 Recommendations

Based on the results of the conceptual design evaluation, it is recommended that final design and implementation of an ET cover proceed for final closure of the Present Landfill. The ET cover design approach can provide a solution to the combined performance requirements of infiltration reduction and longevity that is superior to conventional cover designs. The ET cover can be monitored in the short-term to prove its performance, and then be released from continued maintenance in the long-term.

The Conceptual Design Report presents the technical and engineering basis for the ET cover design to KH, DOE, EPA, and CDPHE. The recommendation to proceed with the ET cover and supporting analyses give RFETS decision-makers the technical basis to proceed with regulatory approval and final design processes. If the decision is made to move ahead with ET design, a site closure decision document that includes the ET cover will be prepared for approval by the regulatory agencies.

References

Campbell, G. S. Unpublished manuscript related to calibration and temperature correction of heat dissipation matric potential sensors. Washington State University. Pullman, Washington.

Colorado Department of Public Health and Environment (CDPHE). 1996. *Final RFETS Cleanup Agreement: Attachment 10.*

Daniel B. Stephens & Associates, Inc. 2001a. *Preliminary draft work plan: Modeling and conceptual design of evapotranspiration covers at RFETS.* Prepared for Kaiser-Hill, LLC, Golden, Colorado. July 23, 2001.

———2001b. *Work plan for modeling and conceptual design of evapotranspiration covers at RFETS.* Prepared for Kaiser-Hill, LLC. November 16, 2001.

Doty, S. 2001. Personal communication from S. Doty (SAIC) to Mark Ankeny (DBS&A).

Earth Tech Environment and Infrastructure, Inc. 2000. *Final ET cap work plan, Landfill 5 (FTC-009), Fort Carson, Colorado.* Contract No. DACW45-94-D-0001. Prepared for U.S. Army Corps of Engineers, Omaha District. March, 2000.

Edil, T.B. V.J Ranguette, and W.W. Wuellner. 1990. Settlement of municipal refuse. *In Geotechnics of waste landfills: theory and practice.* ASTM STP 1070. A. Landva and G.D. Knowles, Eds. ASTM, Philadelphia.

EG&G Rocky Flats, Inc. (EG&G) 1994. *Borrow source evaluation for closure of the OU5 and OU7 landfills.* November 17, 1994.

Environmental Restoration Management (ERM). 1994. *Rocky Flats Environmental Site technical memorandum.* October 1994.

Fayer, M.J. 2000. *UNSAT-H Version 3.0: Unsaturated soil water and heat flow model.* Publ. PNNL-13249. Pacific Northwest National Laboratory operated by Battelle for the U.S. Department of Energy, Richland, Washington.

Gardner, W. R. 1983. Soil properties and efficient water use: An overview. Page 62 *In* Taylor, H.M., W.R. Jordan, and T.R. Sinclair (eds.), *Limitations to efficient water use in crop production*. American Society of Agronomy, Inc., Crop Science Society of America, Inc., and Soil Science Society of America, Inc.

Houghton, H.G. 1985. *Physical meteorology*. MIT Press, Cambridge, Massachusetts.

Kaiser-Hill Company. 1996. *Operable Unit 7 Revised Draft IM/IRA Decision Document and Closure Plan*. March 1996.

———. 2001. E-mail from Marcia Murdock, Kaiser-Hill Ecology Group, to Mark Ankeny, DBS&A, regarding comments from the KH Ecology Group on vegetation at RFETS. April 2001.

Liang, Y.M., D.L. Hazlett and W.K. Lauenroth. 1989. Biomass dynamics and water use efficiencies of five plant communities in the shortgrass steppe. Oecologia 80:148-153.

Means, R.S. 2002. *RSMeans® Heavy construction cost data*, 16th Annual Edition.

Morrison Knudsen Corporation. 1989. *Vegetation resources of Rocky Mountain Arsenal, Adams County, Colorado*. Prepared for Shell Oil Company/Holme Roberts & Owen, Denver, Colorado.

Price, A.B., and Amen, A.E. 1980. *Soil Survey of Golden Area, Colorado- Parts of Denver, Douglas, Jefferson, and Park Counties*. U.S. Department of Agriculture, Soil Conservation Service, In cooperation with Jefferson County and the Colorado Agricultural Experiment Station. 405 pp.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, coordinators. 1997. *Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE*). U.S. Department of Agriculture, Agriculture Handbook No. 703, 404 pp.

Schofield, T.G., et al. 1994. *Comparison of neutron probe and time domain reflectometry techniques of soil moisture analysis.* Pages 130 -142 *In* U.S. Department of Interior, Bureau of Mines, SP Publication SP-19.94. Minneapolis, Minnesota.

Sharma, S. 1995. XSTABL: an integrated slope stability analysis program for personal computer: Reference manual (version 5.00). Interactive Software Designs, Moscow, Idaho. 131 p.

Sharma, H.D., P. Lewis, Sangeeta. 1994. *Waste containment systems, waste stabilization, and landfills: design and evaluation*. John Wiley & Sons, Inc. New York, New York.

Urban Drainage and Flood Control District (DUDFCD). 2001. *Criteria Manual, Volume 1*. Wright Water Engineers, Inc., Project Consultant. Denver, Colorado. June 2001.

U.S. Department of Energy (DOE). 1995. *Geotechnical investigation report for Operable Unit No. 5, Rocky Flats Environmental Technology Site*. Draft, September 1995.

U.S. Department of Energy (DOE). 1996. *Operable Unit 7, revised draft, Im/IRA decision document and closure plan*, RF/ER-96-0009.UN. March 1996.

U.S. Environmental Protection Agency (EPA). 1989. *Technical guidance document: final covers on hazardous waste landfills and surface impoundments.* EPA/530-SW-89-047. July 1989.

———. 1993. *Technical guidance document, QA and QC for waste containment facilities.* EPA/600/R-93/182. September 1993.

———. 1998. *Compilation of air pollutant factors (AP-42). Section 2.4 Municipal Solid Waste Landfills.* November 1998.

van Genuchten, M. Th., F. Leij, and S. Yates, 1991. *The RETC code for quantifying the hydraulic functions of unsaturated soils.* Report No. EPA/600/2-91/065, U.S. Environmental Protection Agency, Office of Research and Development, Washington D.C.

Wischmeier, W.H., and Smith, D.D. 1978. *Predicting rainfall erosion losses-a guide to conservation planning.* U.S. Department of Agriculture, Agriculture Handbook No. 537, 58 pp.